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Backlog Forest Land Rehabiliation in the SBS and BWBS zones in the Northern Interior of British Columbia

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References to the B.C. Ministry of Forests and Lands appear throughout this report. This reflects the name of the Ministry from August, 1986 through July, 1988.

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Study Area 1

1.2 Methods of Investigation 2

1.3 Organization of the Report 2

2 CLIMATE AND SOIL 4

2.1 Biogeoclimatic Units 4
  2.1.1 The Sub-boreal spruce zone 5
  2.1.2 The Boreal white and black spruce zone 7

2.2 Soils 10
  2.2.1 Morainal soils 10
  2.2.2 Lacustrine soils 10
  2.2.3 Fluvioglacial and fluvial soils 11
  2.2.4 Organic soils 12

2.3 Soil Climate 12
  2.3.1 Soil temperature 12
  2.3.2 Soil moisture 14
  2.3.3 Frost-heaving 14

3 BACKLOG NSR IN THE SBS AND BWBS ZONES 16

3.1 Definition and Extent of NSR 16

3.2 Classification of Backlog Types 18

3.3 Classification of Disturbance Types 20
  3.3.1 Wildfire 21
    3.3.1.1 Recent wildfires 21
    3.3.1.2 Old wildfires 21
  3.3.2 Logging 22
    3.3.2.1 Strip logging 22
    3.3.2.2 Diameter logging 22
    3.3.2.3 Clearcut logging 22
  3.3.4 Other disturbances 23
    3.3.4.1 Windthrow 23
    3.3.4.2 Insect damage 23
    3.3.4.3 Pathological agents 23

3.4 Classification of Vegetation Types 23
  3.4.1 Herb complex 24
  3.4.2 Shrub complex 26
  3.4.3 Pure aspen 27
  3.4.4 Mixed deciduous 28
  3.4.5 Overstocked pine 30
  3.4.6 Stagnant pine 30
  3.4.7 Deciduous/conifer 31

4 BRUSH CLEARANCE 32

4.1 Introduction 32

4.2 Hardwood Conversion 32
  4.2.1 Machine clearing 32
  4.2.2 Chemical treatment 33
  4.2.3 Prescribed fire 37

4.3 Wildfire Rehabilitation 38

4.4 Overstocked Pine 39

4.5 Recently Failed Logged Openings 43
  4.5.1 Chemical treatments 43
  4.5.2 Brown and burn 45
  4.5.3 V-plows 46

4.6 Old Logged Openings 46

5 MICROSITE PREPARATION 48

5.1 Introduction 48

5.2 Prescribed Fire 48
  5.2.1 General considerations 48
  5.2.2 BWBS 52
  5.2.3 SBS (Group 1) 53
  5.2.4 SBS (Groups 2 - 5) 53

5.3 Scalping 54
  5.3.1 Effects on seedling performance 54
  5.3.2 Methods 55
    5.3.2.1 Blade scarification 55
    5.3.2.2 V-plows 55
    5.3.2.3 Ripper plow 57
    5.3.2.4 Brush blades 58
    5.3.2.5 Disc trenchers 60
    5.3.2.6 Patch scarifiers 61
  5.3.3 BWBS 63
  5.3.4 SBS 64

5.4 Inverting 66
  5.4.1 General considerations 66
    5.4.1.1 Mounding 67
    5.4.1.2 Moldboard plows 68
    5.4.1.3 Agricultural discs 69
  5.4.2 BWBS 69
  5.4.3 SBS 71

5.5 Mixing 73

5.6 Dragging 74

6 SUMMARY 77
6.1 Perception of Regeneration Problems 77
6.2 Problem Areas 77
6.3 Treatment Successes and Failures 77
6.4 Backlog Classification 84
6.5 Examination of History Records System 84
6.6 Rehabilitation Prescriptions 84
6.7 Priorities for Research 84
7 REFERENCES 86

APPENDICES

1 Case studies 91
2 List of contacts 118
3 Questionnaire 120
4 Perception of regeneration problems 122

TABLES

1 Climatic data for selected stations in the SBS zone 4
2 Climatic data for selected stations in the BWBS zone 8
3 Summary of climatic characteristics and forestry interpretations 9
4 Problem summary 78

FIGURES

1 Location of study area 1
2 Two phases of rehabilitation 3
3 Soil temperatures at 5 and 10 cm depths from selected sites 13
4 Percentage of disturbed area classed as NSR 17
5 Comparison of NSR rates in the study area 18
6 Conceptual basis of backlog classification 19
7 Classification of backlog vegetation by disturbance types 20
8 Relationship between backlog and ecosystem classification 24

8 Relationship between backlog and ecosystem classification 24

9 Aspen clones in the SBSe2(01) 27

10 Spruce understory in the Mackenzie District (SBSo) 29

11 Pine strip-spacing in the Vanderhoof Forest District (SBSi) 41

12 Rehabilitation of overstocked pine in the Vanderhoof Forest District (Long Lake) 42

13 Aerial spraying in the Fort St. John Forest District (BWBSd2) 44

14 Comparison of the percentage use of various methods of site preparation in the BWBS and SBS zones of the northern Interior 49

15 Comparison of the percentage use of various methods of site preparation in the SBS zone within northern Interior forest regions 50

16 V-plow rehabilitation on a subhygric to hygric (OS) ecosystem (spruce-horsetail) in the Mackenzie Forest District (SBSj2) 56

17 Heavy reedgrass competition following rehabilitation of the Osborne Fire in the Fort St. John Forest District (BWBSe) (Case Study 12, Appendix 1) 64

18 An old blade scarification site in the Prince George East Forest District (SBSf) 65

19 Bräcke mounder (I.S.S., Prince George) in operation on a level spruce-horsetail ecosystem in the SBSf 72

1 INTRODUCTION

This report examines the nature and extent of "backlog NSR", and the techniques used to treat it in the northern Interior of British Columbia. The term "backlog NSR" (not satisfactorily restocked) refers to forest land which could be fully stocked with silviculturally acceptable trees but is not, and is not likely to be without intensive rehabilitative treatment.

The report is one outcome of FRDA Project 1.15, entitled "A Problem Analysis of Backlog Forest Lands." The objectives were to examine all aspects of rehabilitation; undertake a review of relevant literature; identify existing practices and perceptions; list successful and unsuccessful treatments; classify backlog types; and develop prescriptions.

1.1 Study Area

The geographic focus of the report is the Sub-boreal Spruce (SBS) and the Boreal White and Black Spruce (BWBS) zones, within the Prince George and Prince Rupert Forest Regions and the Quesnel Timber Supply Area (TSA) in the Cariboo Forest Region (Fig.1). The study area is larger than one-third the size of the province (an estimated 375 000 km^2).

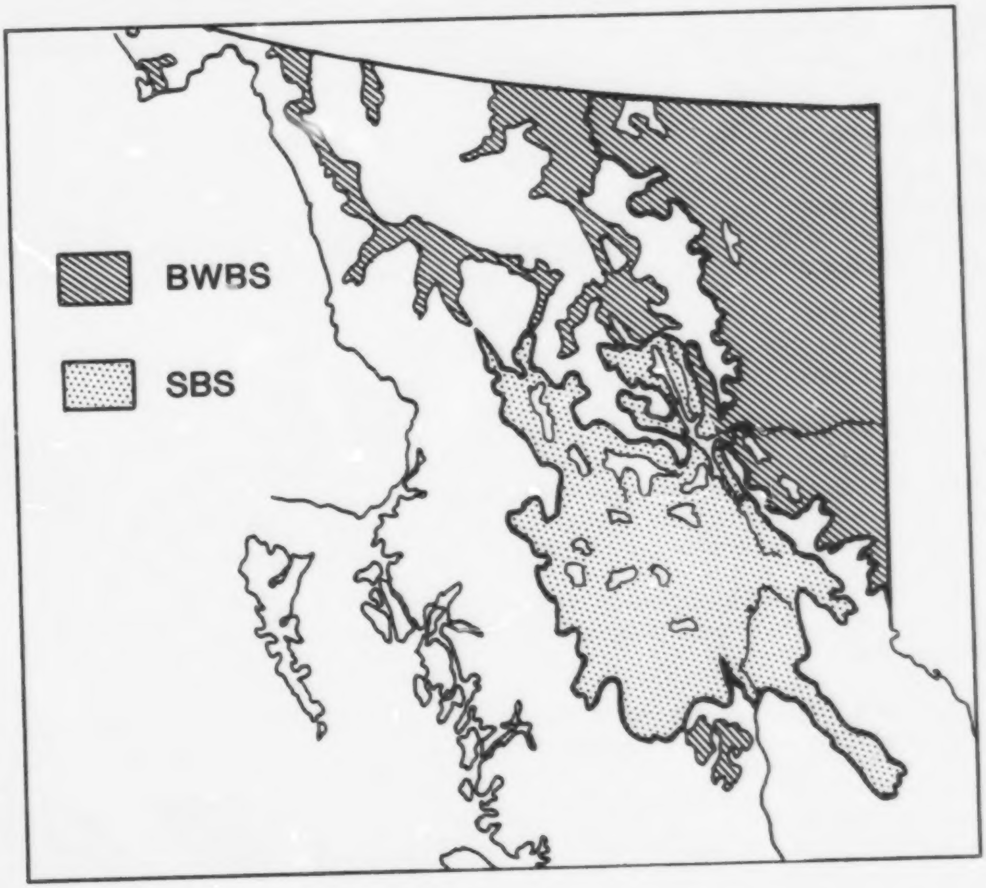

FIGURE 1. Location of study area.

1.2 Methods of Investigation

The subject of backlog forest land was examined to determine the problems of clearing sites of existing vegetation and then of preparing them for the successful establishment of commercially valuable species. Examination took the form of field tours and site assessments, interviews, questionnaires, and a literature review.

As part of the fieldwork, 40 sites, exemplifying successful and unsuccessful silvicultural practices, were visited. In each, a detailed ecosystem description, including soils and competing vegetation, was carried out. The silvicultural history of the block was reconstructed as accurately and completely as possible. Of these 40 sites, 25 were selected as "case studies" and are summarized in this report to illustrate some of the points made in the text. A much larger number of sites were visited, but not described in the same detail. Several sites highlight particular problems in site rehabilitation or microsite preparation and provide another source of information for this report.

In addition to visiting field sites, the author toured the study area to interview licensee and Forest Service silviculturists. All aspects of regeneration and rehabilitation practices were examined. A questionnaire was also sent out to 55 experienced silviculturists, currently specializing in regeneration and/or rehabilitation. Thirty-four responded.

All sources of information were synthesized to produce an account of rehabilitation practices (Chapters 4 and 5). Sources are indicated in the text as personal communication, questionnaire response, case study, observation, or literature reference.

1.3 Organization of the Report

Chapter 2 provides an overview of ecological factors and their silvicultural implications. Although the study area in general has a continental climate distinguishing it from other areas in British Columbia, such generalizations obscure a wide range in precipitation, snow accumulation, soil temperature, soil moisture deficit, and other ecological factors. Differences in any of these factors may have a significant effect on rehabilitation.

Chapter 3 introduces an interim classification of backlog vegetation types observed in the field. It also defines NSR backlog and gives estimates of its extent in the study area.

Chapters 4 (Brush Clearance) and 5 (Microsite Preparation) describe rehabilitation methods that are or have been practised. The review was organized this way because rehabilitation is viewed as consisting of two "phases" (Fig. 2). First, the backlog site must be cleared of brush. Second, biologically suitable microsites must be created in preparation for planting. In some cases, microsite preparation will accomplish a suitable degree of brush clearance; in others, microsites will be created during the course of brush clearance.

Appendix 1 presents a synopsis of 24 case studies. In each one, the site history, treatment impact, and degree of brush competition is summarized. Treatment success is then assessed, and implications for rehabilitation discussed.

The questionnaire is reproduced in Appendix 2, and review of the response is presented. Appendix 3 contains a list of contacts made during the project.

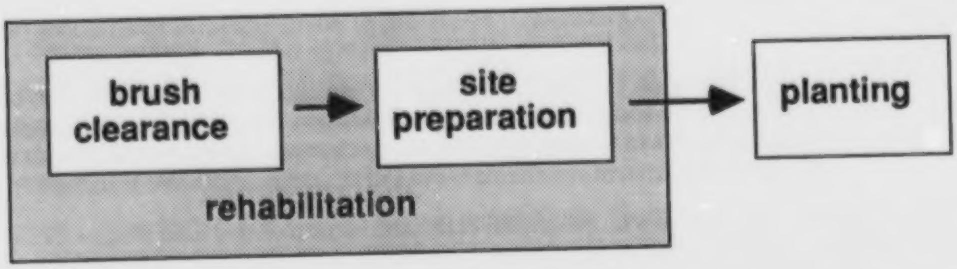
brush clearance
site preparation
planting
rehabilitation

FIGURE 2. Two phases of rehabilitation.

2 CLIMATE AND SOIL

2.1 Biogeoclimatic Units

The study area for this report consists of the Boreal White and Black Spruce and Sub-boreal Spruce zones within the Prince George and Prince Rupert Forest Regions and in the Quesnel TSA of the Cariboo Forest Region. This embraces about 25 biogeoclimatic units and, as such, there is considerable variation from north to south and east to west.

Biogeoclimatic units represent an integration of climate, vegetation and soils (Krajina 1969). Some units differ from others in climatic characteristics that are important for regeneration. Within the limits of the available data base, these characteristics and differences are discussed in the following report sections.

Statements regarding the climate of subzones and variants (Tables 1 and 2) are based on normalized data for the 30-year period, 1951-1980 (AES 1982), on data presented by McLeod and Meidinger (1985), and on unpublished data from McLeod (pers. comm.). Most current data on climate are in the form of averages, such as mean annual air temperature or mean growing season (May to September) temperature. Averages can be useful, but in some cases extreme values, the sequence of events (such as rainfall and warm weather), or the degree of variability itself may be of most importance.

TABLE 1. Climatic data for selected stations in the SBS zone

Station	Unit	Group	Mean annual temperature	Mean summer temperature[a]	Rainfall (mm)	Snowfall (mm w.e.[b])	Days without frost
McGregor	f/j1	1	3.5	12.5	620	328	162
Aleza Lake	j1	1	3.0	12.4	558	339	155
Topley Ldg.	e1	2	2.5	11.3	286	246	156
Fort Babine	e1	2	1.2	10.2	340	261	126
Prince George A	e2	3	3.3	12.2	410	242	170
Burns Lake	e2	3	2.2	11.2	281	185	159
Kalder Lake	e2	3	.2	9.5	348	356	126
Fort St. James	k3	4	2.3	11.7	290	204	150
Quesnel	l	4	5.0	14.0	365	166	182
Alexis Creek	a	5	.4	8.9	270	195	75
Tatelkuz Lk.	a	5	M[c]	10.1	312	197	M
Puntchesakut Lk.	a	5	2.5	11.4	349	178	152

[a] May to September inclusive.

[b] "w.e." refers to water equivalent.

[c] Missing data.

2.1.1 The Sub-boreal spruce zone

This zone has a continental climate with long, cold winters and short, moist summers. The SBS exhibits an annual range of mean monthly temperatures of about 25°C, much more than that on the coast, but less than in the BWBS (Schaeffer 1978). The SBS is somewhat less continental than the BWBS, with slightly milder winters and cooler summers, but its extreme minimum temperatures are nearly as low.

Precipitation is greatest in the easternmost biogeoclimatic units, due to orographic lifting of moist eastward-moving air masses as they approach the Rocky Mountains. Westerly subzones are in the rain shadow of the Coast Mountains, although this effect diminishes towards the east.

In general, mean annual and growing season temperatures decrease with increasing latitude and elevation. Paralleling this decrease are changes in proportion of total precipitation falling as snow, date of snowmelt, length of growing season, and growing degree days. The combination of varying temperature and precipitation regimes results in a complexity of macroclimates across the SBS zone.

To simplify this complexity, biogeoclimatic units with similar macroclimatic characteristics have been combined into five broader "Groups". These groupings were based on the suggestions from the staff of the Ecology Program of the B.C. Ministry of Forests and Lands, and contain units that are not necessarily contiguous. Readers should refer to biogeoclimatic maps of the Prince George Forest Region (McLeod and Meidinger 1985), Prince Rupert Forest Region (Pojar *et al.* 1984), and Cariboo Forest Region (Research Section, unpublished data).

Group 1. "Wet, devil's club units" (SBSj1, j2, f, and n)

These are the easternmost biogeoclimatic units of the SBS, lying on or near the western slopes of the Rocky Mountains. The two selected stations in Table 1 receive about 900 mm of total precipitation (rain and snow) per year. Within this group, total annual precipitation ranges from 542 to 1635 mm (McLeod and Meidinger 1985).

The biogeoclimatic units in this group experience heavy snowfalls. Deep snow limits the depth of soil freezing by insulating the soil. It may also cause limb breakage in susceptible species, particularly lodgepole pine. Wet snow in particular weighs heavily on trees and restricts maneuverability of machines. Snow affects options for backlog rehabilitation, both by physically limiting machine operation and access, and by reducing the depth of soil freezing. This latter effect can be a problem on some sites where frozen soil is necessary for machine access.

The relatively heavy rainfall in these units has numerous silvicultural implications. Soil moisture deficits are likely to be less pronounced and of shorter duration than in areas further west. Since summers are relatively moist in this group, obtaining adequate duff reduction from a prescribed burn can be difficult. Summer burning may be necessary to achieve target impacts on many sites (depending, of course, on soil, terrain and fuel characteristics as well).

The generally wetter conditions lead to relatively heavy vegetative covers and, on some sites, colder soils. In the SBSf, for example, devil's club (*Oplopanax horridus*) is a member of mesic ecosystems (DeLong *et al.* 1986), whereas in drier subzones, this plant is normally confined to subhygric ecosystems. Greater moisture availability allows more vigorous brush competition than in drier subzones to the west, such as the SBSd. While soil temperature and brush competition are problems throughout the SBS zone, they are particularly difficult in Group 1.

Group 2. "Snowy, spruce-balsam units" (SBSl, e1, and m)

These are fairly cool units, in which a relatively high proportion of the total precipitation falls as snow. Total precipitation ranges from 437 to 922 mm (McLeod and Meidinger 1985).

In the Prince Rupert Forest Region, the SBSe1 is distinguishable from other SBS units in that it contains subalpine fir (*Abies lasiocarpa*). As well, it is the wettest and snowiest of the Forest Region's three subzones (SBSe1, d, and a). Tree productivity is greater in the SBSe1 (Pojar *et al.* 1984), partly because it is moister than the SBSd and warmer than the SBSa. The SBSe1 extends into the Cariboo and Prince George Forest Regions, whereas the SBSi is confined to higher elevations in the southwestern part of the Prince George Forest Regions. The SBSm is confined to isolated high elevations east of the Fraser River, surrounded by the SBSk subzone at lower elevations.

The silvicultural implications of Group 2 climate are similar to those of Group 1. The Group 2 climate is neither as moist nor as snowy as the Group 1 climate, but is moister and snowier than other groups. Consequently, soil moisture deficits are likely to be less pronounced than in adjacent Group 4 units; and soils will warm more slowly because of somewhat heavier snow accumulation and later snowmelt. Mean summer and annual temperatures are not consistently different from other groups.

Group 3. "Spruce-balsam, shrubby units" (SBSc, d, e2, and o)

These units are relatively mild with moderate amounts of precipitation. They are less snowy than Group 2 units, with consequently earlier snowmelt and soil warming in the spring, and slightly longer growing seasons.

In the Prince Rupert Forest Region, the SBSd is regarded as intermediate between the SBSa and e1 units, being moister and warmer than the SBSa (Group 5), but drier and warmer than the SBSe1 (Group 2) (Pojar *et al.* 1984).

This group contains units dispersed across the zone. The SBSo ("dry, cold") lies on the shores of Williston Lake, near the foot of the Rocky Mountains. Despite its proximity to Group 1 units, it receives a modest amount of precipitation, ranging from 467 to 671 mm (McLeod and Meidinger 1985). The SBSe2 ("moist, cool") occupies mostly rolling or flat, low-elevation country northeast of Prince George (as well as a narrow salient to the southeast). Both the SBSe2 and o units are confined to the Prince George Forest Region.

The SBSc ("moist, central") receives a similar range of precipitation as the SBSe2 and the o, but is somewhat warmer (although considerable overlap is present between the SBSc and e2). The SBSc subzone occupies a limited area west of the Fraser and Quesnel rivers in the southern Prince George and northern Cariboo Forest Regions.

The SBSd ("dry, cool central") is the driest unit in Group 3, and lacks subalpine fir. The SBSd has its greatest extent in the southern portion of the Prince Rupert Forest Region, where it is extensive throughout lower elevations. It does not extend into the Cariboo Forest Region. Soil moisture deficit is probably most pronounced in this subzone. According to Pojar *et al.* (1984), the SBSd experiences a longer and warmer growing season than the adjacent subzones in the SBSk. Snowmelt and soil warming usually take place earlier.

In general, Group 3 units are neither as cold as Group 5, nor as warm as Group 4 units (with the exception of the SBSc).

Group 4. "Warm, valley units" (SBSk1, k2, k3, h, and l)

The units in Group 4 are characterized by generally high mean annual and growing season temperatures (Table 1) and a large number of growing degree days (McLeod and Meidinger 1985). There is considerable overlap in temperature and precipitation between Group 4 units and those of other groups. Circum-mesic ecosystems in this unit frequently contain Douglas-fir (*Pseudotsuga menziesii*), probably reflecting the warmer conditions.

The SBSk subzone ("dry, warm, southern") extends over relatively low elevations from Stuart Lake in the Prince George Forest Region, south and southeast to Quesnel and Horsefly in the Cariboo Forest Region. To the south, it grades into the IDF zone.

The climate at Fort St. James (Table 1) is more northerly (and thus cooler) than the bulk of the area within the SBSk subzone. In general, the SBSk experiences a relatively warm climate with moderate precipitation. Although growing seasons are likely to be longer here than in adjacent, higher elevation (Group 2) subzones, productivity may be limited by soil moisture deficits.

The SBSl ("dry, warm, central") is the warmest subzone in the SBS, with mean annual and summer temperatures of 4.3 and 13.3°C, respectively (McLeod and Meidinger 1985). Growing degree days are similarly higher (averaging 1349) and "days without frost" more frequent (Table 1: Quesnel).

Group 5. "Dry, pinegrass-moss units" (SBSa and b)

These units are the driest in the zone (with the exception of the SBSd); they also have the lowest summer mean temperatures and the lowest growing degree day totals (A. McLeod, unpublished data).

In the Prince Rupert Forest Region, the SBSa ("pine-spruce subzone") has the driest and coldest climate in the SBS (Pojar *et al*. 1984). It extends from the extreme southern portion of the Prince George Forest Region into the Cariboo, where it is extensive west of the Fraser, and subdivided into three variants. As in the Prince George Forest Region, the SBSa is regarded as having relatively low productivity (Annas and Coupe 1979), due both to low temperature and rainfall. Existing forests commonly consist of even-aged lodgepole pine which has developed following wildfires. Rehabilitation of these forests has been a low priority because of low productivity.

The SBSb ("dry, cool, southern") was seen by Annas and Coupe (1979) as transitional between the "more typical sub-boreal forests" to the north and the IDF zone to the south. The subzone contains Douglas-fir, which it shares with Group 4 units; but its mean annual and summer temperatures are lower in the SBSb than in the units of Group 4.

2.1.2 The Boreal white and black spruce zone

This zone experiences a northern, continental climate, with long, cold winters and short, relatively warm summers (Annas 1983). It has the most continental climate in the province, with an annual range of mean monthly temperatures greater than 30°C over much of the area, and up to 40°C in the northeastern corner (Schaeffer 1978).

Mean annual temperatures are just above 0°C over most of the area (Table 2), falling below freezing in the Fort Nelson area (BWBSa1) and in the northern Rocky Mountain trench area (BWBSe), (McLeod and Meidinger 1985). These means are lower than in the SBS zone, reflecting the severe winter temperatures, especially during the frequent incursions of arctic air masses. The extreme minimum temperature recorded at Fort Nelson between 1951 and 1980 was -51.7°C (AES 1982), one of the lowest recorded in the province. Mean growing season temperatures (May to September, inclusive) range from 11.9 to 12.5 in the BWBSc1 ("moist, cool, southern") variant (Table 2). They are lower in the BWBSd ("moist, cold") and e ("Cordilleran") subzones. The BWBSa1 ("Fort Nelson lowland, northern") has warm summers with a mean temperature of 12.8°C. This variant has a greater number of growing degree days (1262) than other units in the zone, because of long summer days.

TABLE 2. Climatic data for selected stations in the BWBS zone

Station	**Unit**	**Mean annual temperature**	**Mean summer temperature**[a]	**Rainfall (mm)**	**Snowfall (mm w.e.**[b]**)**	**Days without frost**
Fort St. John	c1	1.3	12.5	289	222	172
Dawson Creek	c1	.9	11.9	282	181	153
Hudson Hope	c1	1.9	12.3	247	194	161
Chetwynd	c1	2.0	12.4	268	188	164
Pink Mountain	d	-.5	9.9	336	211	143
Beatton R.	d	-1.2	10.5	296	195	133
Ware	e	-.6	10.5	301	187	122
Ingenika Pt.	e	.5	11.4	307	184	M[c]
Fort Nelson	a1	-1.4	12.8	299	187	146

[a] May to September inclusive.

[b] "w.e." refers to water equivalent.

[c] Missing data.

The BWBSc1 variant, which is of particular interest to this report, has an average Growing Degree Day value of 895, based on 15 stations (McLeod and Meidinger 1985). Fort St. John receives over 2000 hours of bright sunshine per year, more than any other interior station in British Columbia (Schaeffer 1978).

Table 2 shows that "days without frost" generally decrease in number from south to north, reflecting the shorter growing season. However, because incidence of frost is highly sensitive to local conditions, variability within biogeoclimatic units can be high. Frosts can occur in any month, except at Fort Nelson and Fort St. John, where July frosts were not recorded (AES 1982).

The very low winter temperatures east of the Rocky Mountains can be interrupted by incursions of adiabatically warmed air from the west ("Chinooks"). This is reflected in the extreme maximum January or February temperatures recorded east of the Rockies (Fort Nelson: 8.5°C; Fort St. John: 10.6°C; Chetwynd: 10.0°C) compared to stations west of the Rockies (Ware: 3.9°C; Ingenika Point: 5.6°C). Chinooks can last several days, and can damage seedlings by promoting transpiration from frozen soils.

Precipitation is relatively even over the BWBS zone, ranging from 456 mm at Chetwynd to 547 mm at Pink Mountain (Table 2). About a third of this falls as snow. Total precipitation peaks during the summer months, usually taking the form of convectional rainfall. Despite this, long days, high insolation, consistent winds, and relatively warm summer temperatures can produce moisture deficits during the latter part of the growing season. According to Schaeffer (1978), summer moisture deficits of 150 mm have been estimated to occur at lower elevations. Late snowmelt, short growing seasons, and soil moisture deficits combine to make planting windows very narrow in the BWBS zone.

Table 3 summarizes the climatic characteristics in each of the groupings of biogeoclimatic units discussed above. Each parameter, estimated or derived from normalized climatic data (AES 1982, 1984), is ranked on a relative scale within the study area (consisting of both zones). These rankings show that within units or groupings of units, variation may be high. Group 3 in the SBS, for example, exhibits considerable variation in most parameters (reflecting its wide latitudinal range). Many of the parameters are site-dependent; that is, they will vary according to surface or topographic features. For example, winter minimum temperatures and frost-free period will be lower in topographic lows or on north-facing slopes. Similarly, snowpack depth and duration are highly dependent on surface features, such as size and orientation of opening, aspect and slope.

TABLE 3. Summary of climatic characteristics and forestry interpretations

BIOGEOCLIMATIC UNIT

	BWBS				SBS				
Parameter	**c**	**d**	**e**	**e1**	**Group 1 (j2, j2 f & n)**	**Group 2 (e1, l & m)**	**Group 3 (c, d, e2 & o)**	**Group 4 (k1, k2 k3, h & l)**	**Group 5 (a & b)**
Growing Degree Days	High	Mod.	Mod.	V. High	Mod.	Low	Mod. to High	High to V. High	V. Low to Low
Mean Summer Temp. (May to Sept. inclusive)	Mod. to High	V. Low to Low	Low to Mod.	V. High	High	Mod. to Low	V. Low to High	Mod. to V. High	V. Low to Mod.
Mean Summer Precip. (May to Sept. inclusive)	Mod.	High to V. High	Mod.	Mod.	V. High	Mod.	Low to High	Low to Mod.	Mod. to High
Soil Moisture Deficit	*High*	*V. Low to Low*	*Low to Mod.*	*V. High*	*Mod.*	*Low to Mod.*	*V. Low to High*	*High to V. High*	*V. Low to Low*
Winter Minimum Temperature	V. Low to Mod.	V. Low to Mod.	V. Low to Low	V. Low	High to V. High	Mod. to V. High	Mod. to High	Mod. to V. High	Mod. to High
Winter Maximum Temperature	Mod.	Mod.	V. Low	Mod.	High to V. High	Mod.	V. Low High	Mod. to V. High	Mod. to V. High
Snowfall	Low to Mod.	Mod.	Low	Low	V. High	Mod. to High	Low to V. High	Low to Mod.	Low to Mod.
Snow Duration	*Short to Mod.*	*Mod.*	*Long*	*Mod.*	*Long*	*Long*	*V. Short to Long*	*V. Short*	*V. Short to Long*
Frost Free Period	Mod. to Long	Short to Mod.	Short	Mod.	Mod. to Long	Short to Mod.	Short to Long	Mod. to V. Long	V. Short to Mod.
Planting Window (spring/summer)	*Short to Mod.*	*Long to V. Long*	*Mod. to Long*	*Short*	*Mod.*	*Mod. to Long*	*V. Short to Long*	*Mod.*	*Short to Long*

Notes:

1. All interpretations are relative to other biogeoclimatic units within the SBS and BWBS zones.
2. Italicized characters are inferred from estimated parameters.
3. Moisture deficit is inferred from summer precipitation and temperature. It assumes a mesic, well-drained site.
4. Planting window is inferred from snow duration and soil moisture deficit. It assumes planting may begin shortly after snowmelt and continue until the onset of a soil moisture deficit.
5. Snow duration is estimated from snow survey (Water Management Br. 1985) and climatic data (AES 1982).
6. Definitions of classes are as follows:
   Very (V.) High or Long: greater than: (mean of 21 stations plus one standard deviation).
   High or Long: between one-half and one standard deviation above the mean.
   Moderate (Mod.): within one-half and one standard deviation of the mean.
   Low or Short: between one-half and one standard deviation of the mean.
   Very (V.) Low or Short: less than: (mean of 21 stations minus one standard deviation).

2.2 Soils

In this section, broad soil types, classified by parent materials, are briefly described, together with pertinent silvicultural implications. Because of the vast area covered in this report, detailed descriptions are not appropriate. For specific soil survey reports, the reader is referred to Cotic and van Barneveld (1974) for the Nechako-Francois Lake area; Kelley and Farstad (1946) and Keser *et al.* (1973) for the Prince George area; Runka (1972) for the Smithers-Hazelton area; Vold (1977) for the northeast coal area; Valentine (1971) for the Fort Nelson area; and Lord and Mackintosh (1982) for the Quesnel area.

2.2.1 Morainal soils

Morainal material, or till, is the most widespread parent material throughout the study area. In most of the interior plateau, the subdued topography is mantled with varying thicknesses of morainal material. In low-lying valleys and basins, this till may be buried under lacustrine or deltaic deposits. Morainal deposits usually take the form of "blankets", which cover the underlying bedrock surface without obscuring its shape. Surface expression may also take the form of deeper till plains, which may be drumlinized, fluted or kettled.

Morainal material is variable, generally poorly sorted and unstratified. In the study area, most morainal soils exhibit a sandy loam to silty loam texture at the surface, grading to loams or clay loams with depth. Coarse fragment contents normally range from 10 to 40% and consist largely of gravel.

Soils developed on till are usually Orthic Gray Luvisols, grading to Brunisolic Gray Luvisols with increasing moisture. Dystric Brunisols may form in coarser-textured tills. Humo-ferric Podzols are present in the wettest climates, such as the SBSf subzone.

Gray Luvisols are the predominant soil throughout the study area. They have a slightly acid Ae horizon ranging from about 10 to 40 cm thick. Beneath this, a clay-enriched Bt horizon is frequently impenetrable to seedling roots. Consequently, it forms an inappropriate rooting medium. Scalping of the overlying, more friable Ae horizon and planting directly into the Bt horizon will probably result in high seedling mortality and/or poor growth.

Because the Ae horizon contains little incorporated organic matter, it is poor in nutrients, particularly nitrogen, phosphorus and sulphur. For best growth, seedling roots need to tap pockets or layers of soil enriched in organic matter. Thus, mixing or inverting treatments, which conserve organic matter, are most appropriate from the point of view of nutriet supply.

2.2.2 Lacustrine soils

Lacustrine parent materials are common in valleys and basins where pro-glacial lakes formed. They are extensive in three areas: (1) around Fort St. James, Vanderhoof and Prince George; (2) around Williston Lake; and (3) throughout the Peace River basin. Smaller valleys and basins may also contain lacustrine sediments.

These deposits are generally flat or gently undulating, unless they are very shallow, in which case they may simply blanket the underlying bedrock or till. Dissection by rivers and streams has changed the original form in some locations.

Soils are Gray Luvisols, with textures ranging from silt to clay loam and even heavy clay. Lacustrine soils frequently exhibit a clay-enriched Bt horizon which has unfavorable physical properties, as do the Bt horizons in morainal soils. Many of these soils are poorly or imperfectly drained because of the impervious nature of the subsoils. It has been estimated that about 250 000 ha of fine-textured, poorly drained soils of this type are present in the central Interior (Grevers and Bomke 1986).

Lacustrine soils are difficult to manage. Because of their fine texture and subdued topography, soil moisture levels are generally high in the spring, especially during and following snowmelt. Thus, although machine operation is not limited by terrain or stoniness, the soils cannot support heavy traffic during spring. Mechanical site preparation treatments must be carefully timed to avoid soil degradation. In addition, brush competition has been identified as a problem on these soils (e.g., Cotic and Van Barneveld 1974). For optimum production of agricultural crops or tree seedlings, these soils require tillage designed to decrease surface moisture and increase soil temperature, as well as to control weeds. Grevers and Bomke (1986) found that moldboard ploughs were more effective in achieving these goals than were chisel or disc plowing.

The Gray Luvisols developed on lacustrine materials in the BWBS zone resemble those west of the Rockies, except that the Bt horizon is less easily distinguished (Green and Lord 1978). Saturation during the spring may lead to the formation of mottling in some profiles. Competition from reedgrass (*Calamagrostis* spp.) is a particularly serious problem on these lacustrine soils. Tillage treatments to improve soil temperature and moisture regimes must also set back reedgrass, and incorporate its thatch.

2.2.3 Fluvioglacial and fluvial soils

Fluvioglacial materials were deposited by glacial meltwater in various parts of the study area, but are not as extensive as morainal and lacustrine soils. Deposits take the form of terraces, esker complexes, or deltas. Terraces are common along the major river valleys, such as the Fraser, Nechako, MacGregor, and Bowron rivers. Deltaic deposits of sand and gravelly sand can be found at various locations along the margins of lacustrine deposits.

Fluvioglacial parent materials are commonly coarse-textured, ranging from sands to gravels; derived soils are thus well or rapidly drained. Soils are usually Dystric Brunisols (or Humo-ferric Podzols in wetter climates). Because of their low moisture-holding capacity, fluvioglacial soils are usually associated with lodgepole pine stands. On lower slopes and receiving sites, these coarse-textured soils may also be productive for white spruce.

Silvicultural implications of fluvioglacial soils include their potential for serious moisture and nutrient deficiency. Because of the generally shallow nature of the duff layers (which is important both for nutrient and moisture retention) fluvioglacial soils have a high sensitivity to prescribed burning. Recommended stock types are those with high root/shoot ratios (e.g., Pojar *et al.* 1984). Brush competition and frost-heaving are generally not major problems on most fluvioglacial soils (unless in receiving sites). Stoniness may be a slight limitation to mechanical site preparation on some very gravelly outwash materials, but terrain and trafficability are normally conducive to machine operation (with the exception of terrace scarps). Site preparation commonly takes the form of dragging.

Fluvial soils are developed on modern (i.e., post-glacial) floodplains, which may or may not be actively building. They commonly contain high proportions of silt and fine sand, and are productive for both tree growth and agricultural crops. Many such soils have been converted to agriculture. Surface expression and trafficability are, in general, conducive to mechanical treatments, unless water tables are high. In the BWBS, some of the most productive stands of white spruce are on alluvial soils, interspersed between river meanders. Easy access to these sites is therefore limited to the winter, when rivers are frozen.

Silvicultural constraints on fluvial soils include frost-heaving, low soil temperatures, and heavy brush competition.

2.2.4 Organic Soils

Organic soils occur in small isolated areas throughout the SBS zone, usually occupying depressions. In the BWBS zone, they are extensive in the Fort Nelson area, especially where drainage is impeded by shale beds (Valentine 1971). These soils are associated with poor drainage, high watertables, and poor aeration - conditions necessary for the accumulation of organic material.

Veneers of organic matter between 20 and 100 cm are commonly associated with spruce-horsetail ecosystems, identified in most SBS units (e.g., DeLong *et al.* 1986). Whether organic soils (as defined by the Canada Soil Survey Committee 1978), or merely veneers over mineral soil, these soils are difficult to manage. Trafficability is poor, and organic horizons may be too deep for mounders to use mineral soil as a capping. They are also subject to low soil temperatures (being slow to warm in the spring), heavy brush competition, and restricted options for mechanical site preparation. Frequently the soils are treated by ripper ploughs during the winter, when they are frozen. Even then, a high water table may remain a problem.

2.3 Soil Climate

2.3.1 Soil temperature

Silviculturists generally perceive low soil temperature (along with brush competition) to be the most serious ecological constraint to regeneration in the northern Interior (see Appendix 4). Most of the soils in the study area fall into the "Cold Cryoboreal" soil temperature class (Lavkulich and Valentine 1978). In general, soils in the SBS and BWBS zones have mean annual temperatures (at 50 cm depth) between 2 and 8°C.

Soil temperatures for soil climate classification are taken at 50 cm to avoid diurnal fluctuations (Black 1982), but temperatures at shallower depths are more important silviculturally. Figure 3 shows the annual pattern of soil temperatures for depths of 5 and 10 cm at Prince George, Beaverlodge and Fort Vermillion (representing the SBSe2, the BWBSc1, and the BWBSa1, respectively). The data represent 30-year normals under a short grass cover (AES 1984). Thus, although the curves do not represent soils under forest cover, they are fairly representative of recently denuded sites.

At Prince George (Fig. 3), the soil is frozen at 5 cm between late December and late March on average. The depth of frost extends beyond 20 cm but not to 50 cm.

At Beaverlodge in Alberta, across the border from Dawson Creek, soils are frozen between early November and early April, and freezing extends below 50 cm but not to 100 cm. This reflects the more severe winters in the BWBS compared to the SBS. The Beaverlodge station has a mean annual soil temperature at 5 cm of 4.7°C, compared to 6.6°C at Prince George.

Fort Vermillion, in northern Alberta, has roughly the same mean annual soil temperature as Beaverlodge, despite its more northerly location. Summer soil temperatures are considerably higher than at Beaverlodge or Prince George, reflecting the more continental climate and longer days.

At Prince George, soil temperatures exceed 5°C in early May at 5 cm depth and in late April at 10 cm. The 20 to 25°C optimum for white spruce root growth (R. McMinn, pers. comm.) is rarely attained before July. Mean afternoon temperatures in July reach 19.3°C at 5 cm at Prince George, 18.3°C at Beaverlodge, and 24.1°C at Fort Vermillion.

The soil temperatures described here are for only one soil type in each station. Soil temperature regimes depend on soil and site factors such as soil moisture, organic matter content, texture, porosity, duff thickness, aspect, and degree of shading, in addition to the prevailing climate. Mean annual soil temperatures are usually well correlated with mean annual air temperatures (within macroclimatic regions), but the degree and pattern of fluctuation about the mean are subject to local conditions. For example, a dry mineral soil will experience a greater annual temperature range than a moist mineral or organic soil. It will cool to a lower temperature during winter, but will warm faster in the spring. Wet soils are cold soils, primarily because of the high heat capacity of the soil water.

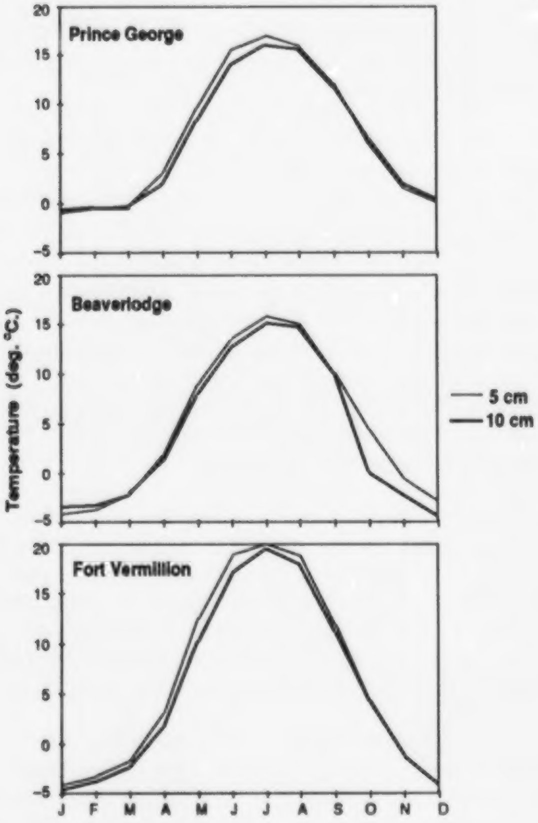

FIGURE 3. Soil temperatures at 5 and 10 cm depths from selected sites.

The presence of duff layers on untreated, logged surfaces strongly affects soil temperatures. The duff has a low thermal conductivity, consequently heat penetration is restricted. Removal of duff layers (scalping) can significantly increase mineral soil temperatures. For example, McMinn (1983) found scalping and mounding increased soil temperature at 6 cm by 6 and 9°C, respectively, over untreated soil in the SBSj1.

The depth and duration of snow affect soil temperature. Because snow, like duff, has a low thermal conductivity, it has the effect of insulating underlying soil from intense cold. The deeper the snow, the greater the insulating effect. For example, in Wisconsin, frost penetration was usually greater on south-facing slopes than on north-facing ones, presumably because snow cover was shallower (Sartz 1973). On the other hand, late-lying snow on north aspects obviously shortens the growing season and delays soil warming.

Shading is another factor affecting the energy balance at the soil surface. Shading by vegetation reduces the incident solar radiation, which is the driving force in soil temperature regimes. This is compensated to a minor degree by interception of long-wave radiation loss, which together with reduced insolation, results in diminished diurnal fluctuation.

Moist soils are cold soils for several reasons. They require high energy inputs per unit temperature increase (i.e., they have high heat capacities), and they generally have thick duff layers and heavy vegetative covers shading the ground.

Steep, north-facing slopes also suffer cold soil problems. Spring warming is delayed both by late-lying snow and reduced insolation.

2.3.2 Soil moisture

Although not generally considered a major ecological problem in regeneration in the northern interior (Appendix 4), soil moisture deficit can lead to mortality or stunted growth. For example, Burdett *et al.* (1984) have hypothesized that planting check in bareroot seedlings is partly a result of restricted uptake of water during the 1st year after outplanting. They observed that increasing moisture can improve growth during that critical period. Container stock is apparently less susceptible to drying out in the 1st year, though it may exhibit symptoms of planting check in the 2nd year (Burdett *et al.* 1984), probably because the resources of the plug material are exhausted.

The ability to regenerate fine roots rapidly in their new environment is a critical factor affecting outplant performance (Leaf *et al. 1978)*. Immediately after outplanting, a young bareroot seedling must depend on its shocked, and frequently deformed, root system to deliver water to the shoot. Existing roots must extract water from a limited volume of soil and, during this critical time, soil moisture must not fall below a threshold value (Sutton 1978). Moisture contents at field capacity are optimum for root development and seedling survival, particularly for the first few weeks after outplanting. Dry weather conditions soon after planting can lead to high mortality. Thus, timing is critical, especially in summer planting.

During August, in drier biogeoclimatic units of the SBS and in much of the BWBS, soil moisture falls below field capacity in most well-drained soils. As a result, productivity probably drops off rapidly. Furthermore, soils on denuded sites that support a dense cover of herbaceous or grassy vegetation may have their moisture depleted by vigorous evapotranspiration. This may pose a significant competitive threat on some sites.

Soils in many ecosystems, such as the spruce-horsetail or black spruce-sphagnum units, have excessive soil moisture. Extensive forests on silty or clayey lacustrine soils in both zones have periodic excesses of soil water that significantly affect soil trafficability, as well as its regeneration and productivity.

2.3.3 Frost-heaving

Frost-heaving, a problem affecting planted seedlings throughout the SBS and BWBS zones, has frequently negated the otherwise beneficial effects of site preparation. It occurs when an ice lens forms beneath the surface of the soil, lifting the surface soil, litter, and outplanted seedlings. The effect is to break or disrupt root systems and expose them to desiccation. Plug stock is perceived to be more susceptible to frost-heaving than is bareroot (e.g., Lloyd 1982).

For frost-heaving to take place, several conditions must be met. Freezing and thawing cycles must induce soil ice formation and subsequently melt it so the cycle can begin again. As well, diurnal temperatures must rise above freezing during some part of the day and then dip below freezing.

The highest frequency of freeze-thaw cycles tends to be when mean monthly air temperatures are near zero. This corresponds to April, October, and November in most parts of the SBS, and to April and October in most parts of the southern BWBS. Since most of the SBS and BWBS is snow-covered in much of April and November, October is the month in which most frost-heaving takes place.

The presence of duff tends to inhibit frost-heaving, because of its insulating properties. Frost- heaving is much more pronounced on exposed mineral soils.

In addition, a reserve of water must be available for frost-heaving to take place. It will not occur in dry soils.

Finally, the soil must have appropriate physical properties to allow water to move to the freezing surface. Soils with high unsaturated hydraulic conductivity (i.e., those offering relatively little resistance to unsaturated capillary flow) are most susceptible to frost-heaving. Medium-textured soils generally fall into this category. In coarse-textured soils, capillary flow is impeded because water films are distributed discontinuously in large pores. In fine-textured soils, the large particle surface area resists unsaturated capillary flow, and thus water transport is not fast enough to keep up with the freezing rate (Ballard 1981). However, capillary flow is not dependent only on texture. For example, compaction of coarse-textured soils (say, loamy sands) may increase hydraulic conductivity by making the soil pores more continuous, and thus may increase susceptibility to frost-heave.

Soil susceptibility to frost-heaving can be grouped into three classes (Soil Survey Staff, U.S. Department of Agriculture, 1971) as follows:

Low	**Medium**	**High**
sand	clay	silt
loamy sand	silty clay	silt loam
coarse sandy loam	sandy loam (medium)	silty clay loam
	sandy clay loam	loam
	sandy clay	clay loam
		very fine sandy loam
		fine sandy loam

3 BACKLOG NSR IN THE SBS AND BWBS ZONES

3.1 Definition and Extent of NSR

Not Satisfactorily Restocked (NSR) land is defined as productive forest land that is supporting less than the minimum stocking level of silviculturally acceptable tree species, as defined by the regional stocking standards. Throughout the study area, that minimum stocking standard is 700 stems per hectare. If more than a set allowable time has elapsed since denudation, NSR land is considered "backlog." This time period, "the allowable regeneration delay," varies across the study area according to biogeoclimatic unit and ecosystem association. The delay may be short on brush-prone sites, where early establishment is critical; it may be longer for natural regeneration than for artificial regeneration. Forest land that is deemed NSR before the regeneration delay has elapsed is classified as "current" rather than "backlog."

Only healthy, well-spaced stems of preferred and acceptable species should contribute to stocking standards. How preferred and acceptable species are defined can greatly affect NSR statistics. The preferred and acceptable species in the study area include spruce (white and hybrid), lodgepole pine, and interior Douglas-fir. Some sites, however, also contain subalpine fir and occasionally black spruce. If this is included in the stocking rate calculation, it could greatly bias NSR statistics, particularly in areas where the species makes up a large part of the natural regeneration. (The fastest way to reduce NSR backlog estimates would be to include subalpine fir as an acceptable species.) Similarly, the proposed upgrading of aspen to a silviculturally acceptable species in the BWBS of the Prince George Forest Region would notably alter NSR statistics.

According to regional stocking standards, subalpine fir is unacceptable everywhere in the Prince George Forest Region. In the Prince Rupert Forest Region, it is acceptable in certain ecosystems within the SBSe1 biogeoclimatic unit. In the Cariboo Forest Region, it is acceptable in mesic and wetter ecosystems in the SBSb and c subzones.

Statistics on NSR were obtained through Silviculture Branch's History Record System (HRS), from a report dated 31 October 1986. For the purpose of this report, NSR in openings greater than 5 years of age were classed as backlog, and NSR in openings less than 5 years old were classed as current. This definition corresponds closely to FRDA standards for interior allowable regeneration delay, although it does not separate out high brush sites, for which the delay is only 2 years. Since brush-prone sites are believed to carry a disproportionate amount of NSR land, these results overestimate current NSR and underestimate backlog land.

The HRS data indicate that just under 500 000 ha are classified as NSR land. About 70% of that total, or 345 166 ha, is located in the SBS zone. By region, the majority of NSR land in the study area falls within the Prince George Forest Region, totalling 381 616 ha or 78% of the total NSR in the area. The BWBS zone accounts for 144 088 ha of NSR (for good and medium sites only), or 29% of the total, even though only 19% of the disturbed area was located in that zone.

Figure 4 shows the percentage of disturbed area classed as NSR. According to this, the BWBS zone accounts for a disproportionately large amount of NSR land. This is undoubtedly the result of the extensive area affected by wildfire in the past, associated with settlement, land clearing and early resource development. In terms of current NSR, the BWBS zone still has a higher amount than the SBS zone. This seems to reflect the difficulty of establishing plantations in the BWBS because of competition from aspen and reedgrass. The Cariboo Forest Region (Quesnel TSA) shows a remarkably low rate of current NSR, though the data probably underestimate the actual NSR rate by several times (O. Steen, pers. comm.).

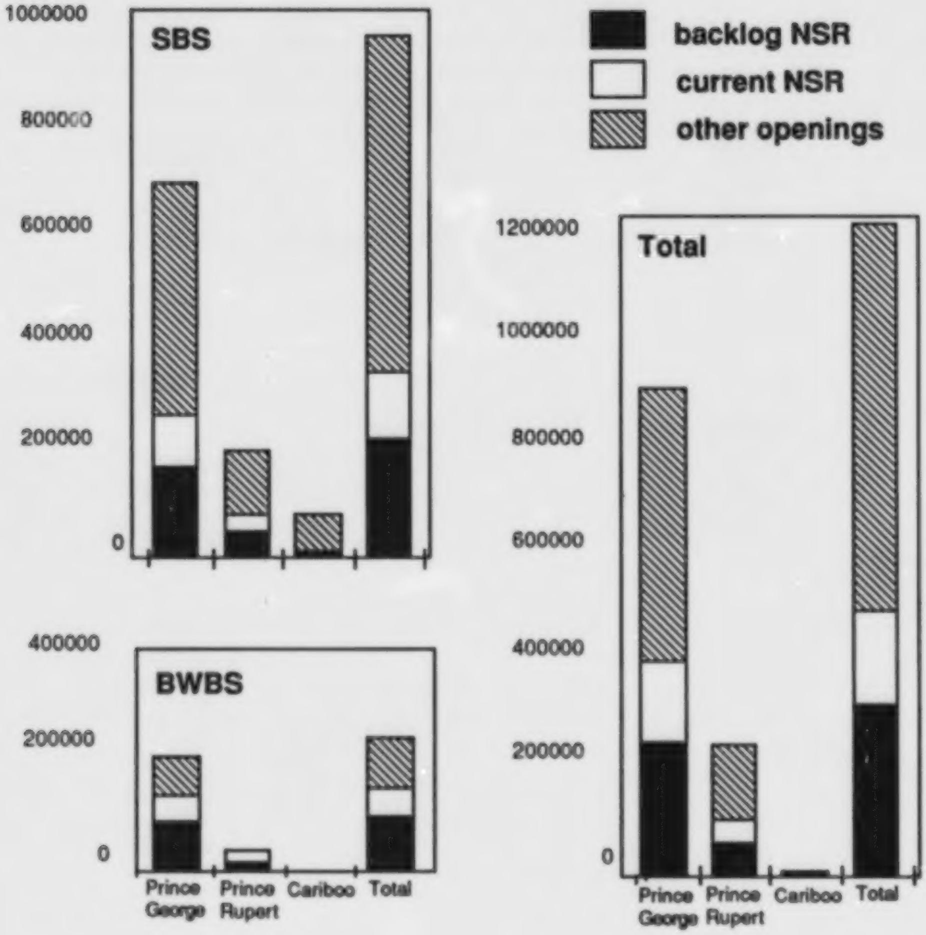

FIGURE 4. Percentage of disturbed area classed as NSR.

Figure 5 shows the NSR rate within the SBS and BWBS zones, compared with other biogeoclimatic zones in the area. Both the BWBS and the ESSF zones stand out as having significantly higher rates of NSR than other zones. The high rate for the BWBS is influenced by wildfire. In the Prince George Forest Region, both the BWBS and the ESSF have high rates of NSR, which is, to some extent, an index of the poor regeneration success rate.

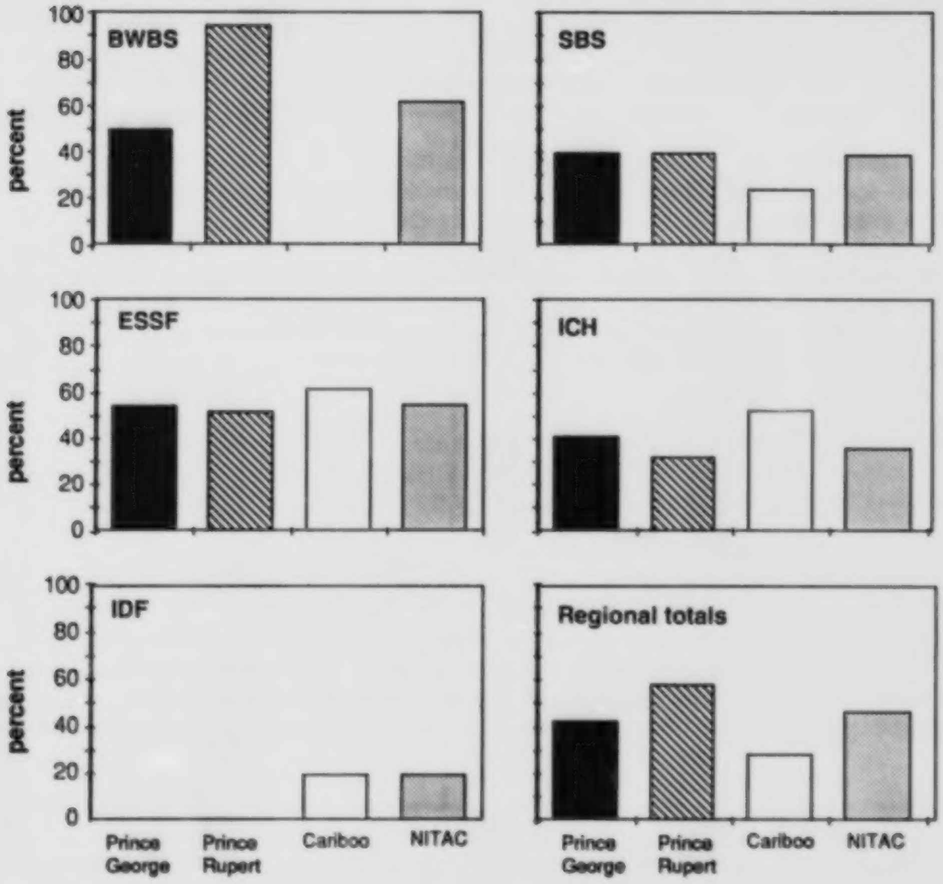

FIGURE 5. Comparison of NSR rates in the study area.

3.2 Classification of Backlog Types

An aim of this project was to construct a classification of backlog types that are prevalent in the northern Interior. Variability both between and within biogeoclimatic units of the SBS and BWBS zones made this a difficult task. The types of vegetation confronting the rehabilitation forester do not always conform to the Biogeoclimatic Ecosystem Classification (BEC). A prime example is aspen, perhaps the single most important backlog brush species in the region. It occurs throughout the SBS and BWBS zones, and across the hygrotope and trophotope ranges. This wide ecological occurrence complicates its definition in ecosystem terms. Overstocked pine, resulting from recent wildfires, similarly ranges broadly over several biogeoclimatic units and ecosystems.

Rehabilitation deals primarily with seral vegetation. Since the BEC is based on climax or maturing seral forest ecosystems, it is not inherently suitable for backlog classification. Attempts are under way to develop a classification of seral vegetation within the BEC,[1] but it is too soon to apply this work across the study region.

The backlog classification proposed here does not supersede the established ecosystem classification used by the B. C. Ministry of Forests and Lands. It merely forms a framework for describing existing rehabilitation practices. Backlog types are relevant largely in the brush clearance stage of backlog rehabilitation; once a site is cleared, the existing ecosystem classification is required for further (microsite preparation) treatment prescriptions (Figure 6).

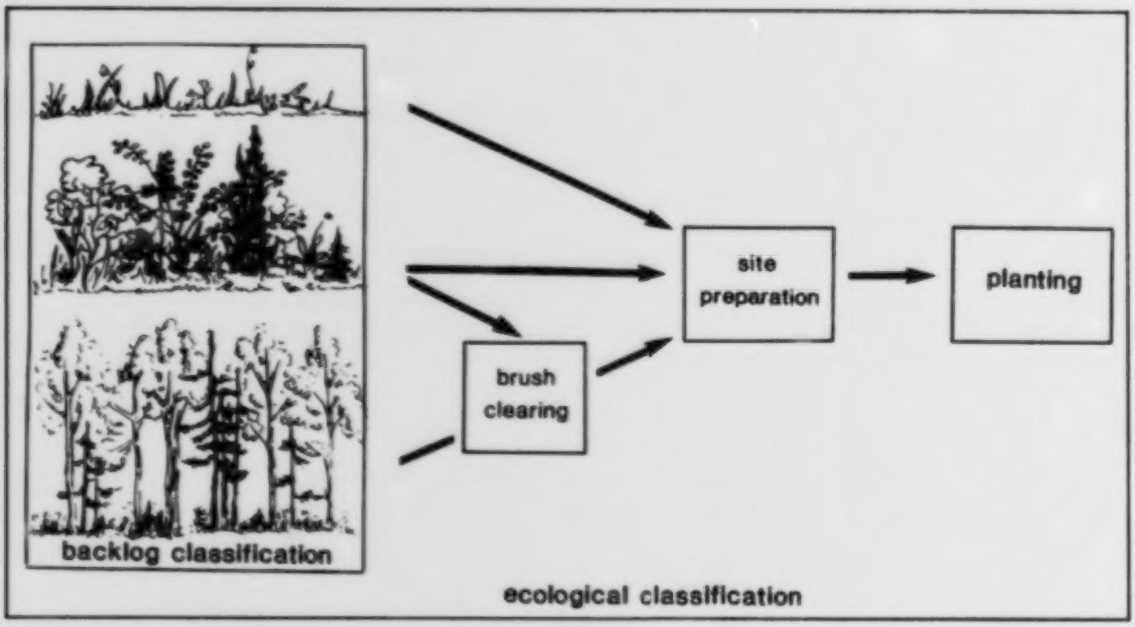

FIGURE 6. Conceptual basis of backlog classification.

This report does not examine successional pathways associated with specific sites and site treatments. Current attempts to predict seral vegetation may yield great benefits in vegetation management and site treatment planning (C. DeLong, pers. comm.). Only a general discussion of the types of backlog vegetation is presented here.

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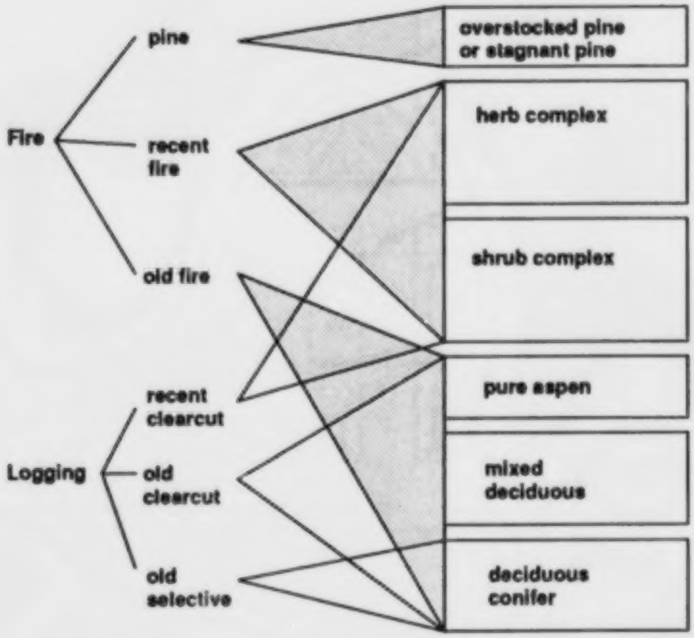
[1] Hamilton, E. 1986. An analysis of the classification and sampling of successional ecosystems within the ecosystem classification programme. B.C. Min. For., Res. Br., Victoria, B.C. Unpubl. ms.

3.3 Classification of Disturbance Types

The composition of vegetation on backlog sites depends in part on the way in which it was created. A classification based on cause of disturbance is one possible way of approaching the problem. Three broad groups of disturbance can be recognized:

1. wildfire
2. logging
3. other

These are discussed and subdivided into more detailed "classes" and "types" below. Backlog types describe the vegetation structure that is likely to be encountered. Figure 7 summarizes this interim classification.



Fire
pine
recent fire
old fire
Logging
recent clearcut
old clearcut
old selective
overstocked pine or stagnant pine
herb complex
shrub complex
pure aspen
mixed deciduous
deciduous conifer

FIGURE 7. Classification of backlog vegetation by disturbance types.

3.3.1 Wildfire

Wildfire is an important ecological determinant of forest structure throughout the study region, particularly in the BWBS zone and western parts of the SBS zone (Groups 1, 3 and 4). It is largely responsible for the mosaic of deciduous and coniferous cover that is characteristic of these northern forests. The extent of pure aspen or aspen-dominated stands is a testimony to widespread wildfire. Most older lodgepole pine forests probably owe their existence to wildfire. Its incidence is thought to have reached a maximum during the hundred years up to the middle of this century, when settlement, railroad construction, and early resource development triggered numerous anthropogenic wildfires (see Pojar *et al.* 1984). Since then, protection measures and increased concern for the economic consequences of accidental fire have diminished its extent - although accidents, lightning, and, to a lesser extent, escaped slashburns, still contribute to a continued incidence of wildfire.

Ecologically, backlog created by wildfire may not differ significantly from that created by logging followed by slashburning. The main differences between the two - for rehabilitation - are the presence of snags (after wildfire), the size and shape of the opening, the ground impact (which may be greater after wildfire than after a prescribed burn), and the amount and distribution of fuels. Consequently, in this classification both recent wildfire and logging overlap in the creation of early seral stage backlog types, namely the "herb complex" and "shrub complexes" (Fig. 7).

3.3.1.1 Recent wildfires

Recent wildfires are those in which herb or shrub complexes are present; that is, the backlog vegetation is less than about 5 m in height. Depending on the productivity of the site, the corresponding age of the vegetation may vary between 5 and 20 years. Major wildfires such as the Paul and Swiss in the SBSd subzone, the Straw in the SBSj1 unit, and the Osborne wildfire in the BWBS zone are current targets for rehabilitation.

When wildfire rages through a mature stand of timber, a sea of snags may remain. Salvage logging is only an option for approximately 2 years, after which the onset of "check" renders the timber unmerchantable. If left standing, snags complicate the rehabilitation of the site, in particular, interfering with aerial herbicide application.

3.3.1.2 Old wildfires

Old wildfires are associated with vegetation at later seral stages, including pure aspen and mixed deciduous stands. These have been created by wildfires that burned more than 10 or 15 years ago. By definition, the average height of the deciduous trees is greater than 5 m.

Although canopies are well established and more or less continuous, an understory of brush, grass (in the BWBS), and/or coniferous species (namely interior spruce or subalpine fir) is usually present. If spruce is a part of the understory community, the definition of NSR requires that it be present at unacceptable stocking rates (i.e., less than 700 stems per hectare). Rehabilitation of old wildfire sites in some areas is considered to be "hardwood conversion". However, stands over about 40 years of age are generally low priorities for rehabilitation (M. Bruhm, pers. comm.).

Overstocked or stagnant pine is another backlog type that can develop following old wildfire.

3.3.2 Logging

Most NSR backlog in the northern Interior is the result of logging. Two major subclasses can be identified:

1. old Intermediate Utilization (I.U.) logging, including strip and diameter logging; and
2. clearcuts, both recent and old.

3.3.2.1 Strip logging

Intermediate Utilization logging was prevalent during the 1960's and early 1970's throughout the study area, consisting of either strip or diameter logging. Strip logging involved cutting all trees in a strip about 50-100 m wide and selectively cutting in leave-strips about the same width. (In many areas these cut- and leave-strips exhibit a herring-bone pattern.) Logging practices varied widely over the region. The objective was usually to facilitate natural regeneration of spruce, which would theoretically seed into the harvested strips from adjacent seed trees, thus forming the new crop.

Unfortunately, the system mostly failed to produce adequate restocking, and the harvested strips brushed in. Failure to restock may also have been due to lack of site preparation or poor timing of treatment in relation to seed availability (R. McMinn, pers. comm.). Since most strip-logged I.U. stands are about 15-30 years old, they do not comprise a range of seral stages as does the wildfire disturbance class. The most common backlog types are deciduous/conifer complexes, which pose a unique rehabilitation situation. Since the leave strips may contain merchantable timber, there may be an option to allow logging, which can precede or accompany rehabilitation of the brushed-in cut-strips.

3.3.2.2 Diameter logging

Diameter logging was common in old stands containing uneven-aged spruce. It commonly left inferior or damaged stems of spruce, and subalpine fir which was generally undesirable.

The vegetation that follows diameter logging is a mosaic of coniferous (particularly subalpine fir) and deciduous trees. The backlog type can be described as deciduous/conifer, in a pattern that is peculiar to diameter-logged stands. Options for rehabilitation may be more limited than for strip logging, since the remaining subalpine fir may be less commercially attractive. On the other hand, falling in preparation for a broadcast burn may be accomplished.

3.3.2.3 Clearcut logging

Clearcut logging had become the normal practice by the 1970's. Throughout that decade, many clearcuts were left to regenerate naturally, even though treatments needed to promote natural regeneration were frequently not applied (R. McMinn, pers. comm.). Plantation failure was prevalent, and many of these failed clearcuts now constitute backlog NSR. Although site preparation and/or planting have become the norm in the recent 6 or 7 years, plantation failure is still too frequent, especially on brush-prone sites.

Backlog clearcuts are classified according to seral stage in the same fashion as wildfires. Recent clearcut failures are characterized by vegetation in an early seral stage, namely herbaceous and shrubby (up to 5 m in height) complexes. Old clearcut failures (normally dating from the late 1960's) support intermediate seral stages, namely immature mixed deciduous, pure aspen, or deciduous/conifer forest with closed canopy. Clearcut failures, unlike wildfires, do not contain abundant snags to complicate rehabilitation, and closed-canopy brush commonly has a poorly developed understory. Both recent and old clearcut failures contain, in most cases, some stocking of a silviculturally acceptable species, consisting of those individuals, planted or natural, which have survived despite vigorous competition. By definition, stocking ranges from just under 700 to 0 stems per hectare.

3.3.4 Other disturbances

The "other disturbance" class includes windthrow, insect, and pathological causes of backlog NSR. In the study region, these are a relatively insignificant cause of backlog land.

3.3.4.1 Windthrow

Rehabilitation of areas affected by windthrow usually involves salvage logging followed by broadcast burning or mechanical treatments. It is distinguished from other types of rehabilitation by the danger involved in bucking stressed stems, and by the limitations to machine maneuverability imposed by uprooted stumps.

3.3.4.2 Insect damage

Backlog due to insect damage is minor. It includes some stands damaged by spruce beetle (*Dendroctonus rufipennis)* which is mainly active in the Bowron Valley east of Prince George. Most accessible beetle-killed stands are salvage-logged, in which case sites should be considered under the logging disturbance class. Mountain pine beetle (*Dendroctonus ponderosae*) has infested enormous areas of lodgepole pine in the province - more than wildfire in 1985 - including 11 000 ha in the Prince Rupert Forest Region and about 1000 ha in the Prince George Forest Region as of 1985 (Wood and Van Sickle 1986). However, since a small proportion of infected stands is actually killed, pine beetle does not contribute greatly to regional NSR figures. Beetle-infested stands affect rehabilitation of adjacent NSR blocks because they constitute a greater fire hazard, thus reducing the attractiveness of prescribed fire as a treatment.

3.3.4.3 Pathological agents

Mortality of stands due to pathological agents is limited, except possibly in the case of mistletoe-infested pine stands. Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) is present throughout the study area, but is not considered either a threat or a contributor to NSR backlog there. However, rehabilitation of mistletoe-infected pine is an on-going concern in adjacent parts of the Cariboo Forest Region.

3.4 Vegetation Types

Figure 8 shows the relationship between the backlog and the ecosystem classifications. Vegetation types need to be subdivided and sorted according to existing ecosystem units. Each vegetation type will occur in a wide range of ecosystems. The herb complex, for example, will be present following disturbance on most ecosystem units in the study area, although its composition will not be the same in all units. Because successional development depends on disturbance as well as on site characteristics, specific correlations between backlog vegetation types and ecosystem units have not been undertaken.

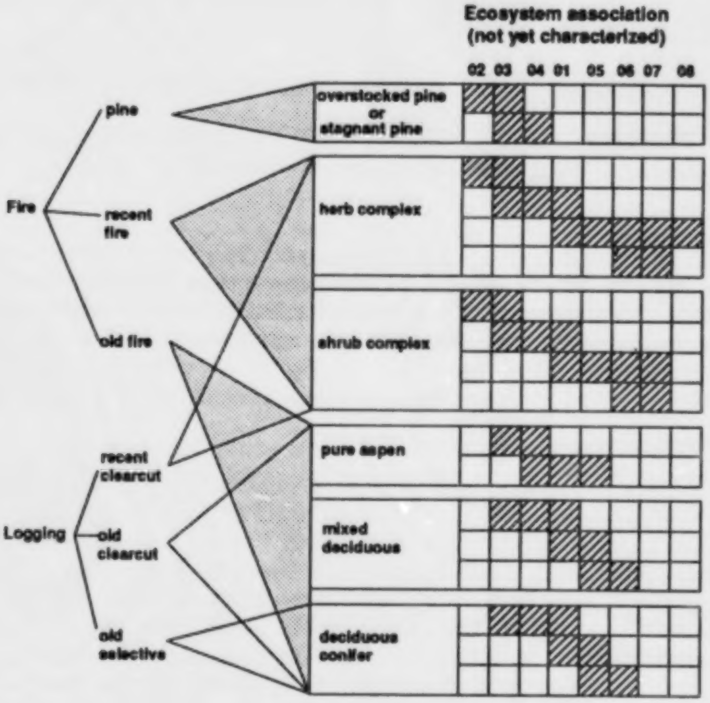

Ecosystem association
(not yet characterized)
02 03 04 01 05 06 07 08
Fire
pine
recent fire
old fire
Logging
recent clearcut
old clearcut
old selective
overstocked pine or stagnant pine
herb complex
shrub complex
pure aspen
mixed deciduous
deciduous conifer

FIGURE 8. Relationship between backlog and ecosystem classification. Shaded areas delimit ecosystem groupings.

3.4.1 Herb complex

Definition

This complex is defined as being less than about 2 m high. It can develop following wildfire (in which case snags are usually present) or recent logging. The species making up this complex develop from seed or from surviving root systems, and colonize a site within 1 or 2 years of disturbance.

Nature and development

Some species are prolific seeders, colonizing denuded sites quickly. Fireweed is probably the best example of this type of specialist plant, and indeed, forms a major competitor in plantations established in very recent burns (although it also reproduces from rhizomes). Asteraceous species such as hawkweed (*Hieracium* spp.), thistle (*Cirsium canadensis*), and pearly everlasting (*Anaphalis margaritacea*) are other examples.

The seed from which competing vegetation develops may arrive on the site following disturbance (transported by wind or animals), or before. In the latter case, the nature of the seedbank, stored in the duff layer before logging, may determine the course of succession following disturbance. Many berry-producing species whose seed is disseminated by animals may also colonize disturbed areas through seed-banking. Examples include thimbleberry (*Rubus parviflorus*), red raspberry (*R. idaeus*), black twinberry (*Lonicera involucrata*), and elderberry (*Sambucus racemosa*) (Coates and Haeussler 1986a).

Other species produce seed that are not viable over long periods of time, and can therefore only invade by seeding-in after a site is disturbed. Willows (*Salix* spp.), sitka alder (*Alnus viridus* ssp. *sinuata*), and birch (*Betula papyrifera*) are examples of these species.

Many species can also reproduce by vegetative means, such as sprouting. If regenerative parts (e.g., roots, rhizomes, and stumps) survive disturbance, sprouting may occur. Vegetative reproduction can be highly significant because species exhibit faster height growth if they sprout from a pre-existing root system than if they grow from seed.

Species composition and rate of colonization depend strongly on the type of disturbance and degree of mineral soil exposure. For example, light treatments such as light burns or winter windrowing may leave root systems intact, thus favoring sprouting species such as raspberry and thimbleberry if they were present in the pre-disturbance stand. Alternatively, drastic treatments or intense wildfires that expose much mineral soil will promote establishment of birch, alder, willow, or cottonwood, depending on seed supply.

Most species in the herb complex are herbaceous, but significant amounts of shrubs, ferns, and grasses may also be present. Species composition varies widely across the study region.

Subhygric to subhydric sites

In subhygric to hygric ecosystems, which correspond to early seral stages of "devil's club" and "horsetail" associations of the SBS described in Coates and Haeussler (1984), the herb complex consists of a distinctive array of species.

On wetter sites that have been burned (either by wildfire or prescribed fire) the complex commonly contains a higher proportion of shrubs than it does on drier sites. The reason is that pre-existing underground root systems can survive even a hot fire in the thick duff layers characteristic of these subhygric and hygric sites.

Plantation failure is disproportionately high on these sites, mainly because vegetative competition is so strong (D. Presslee, pers. comm.). Common species include lady fern (*Athyrium felix-femina*), thimbleberry, black twinberry, elderberry, wood horsetail (*Equisetum sylvaticum*), Indian hellebore (*Veratrum viride*), and the ubiquitous fireweed.

Paper birch, cottonwood (*Populus balsamifera*), sitka or mountain alder (*Alnus viridus* ssp. *sinuata* and *A. incana* ssp. *tenuifolia*, respectively), and various species of willow may occupy the site soon after denudation. These soon exceed the 2-m limit for this vegetation type, in which case it becomes a shrub complex.

Eis (1981) found that vegetative competition was severe on an alluvial site (probably ecosystem unit SBSe2/09.1, Spruce - Horsetail - Red-osier dogwood), because competing species were present under the discontinuous canopy before logging. Following canopy removal, these species (mainly black twinberry and mountain alder) were able to reproduce from established root systems. Consequently, brush competition was so intense that the annual height growth of planted spruce was less than 2 cm and suffered high mortality.

On a "devil's club" site (probably ecosystem unit SBSe2/08: Devil's club - Lady fern), Eis (1981) reported that competing vegetation was slower to establish following clearcut logging, because species had to establish from seed. He also found grass species (*Calamagrostis* spp., *Cinna latifolia*) to be common after logging in this ecosystem. Nevertheless, brush competition can be high within 2 years on these ecosystems (DeLong *et al.* 1986).

Mesic to subxeric sites

On drier sites, including those on mesic to subxeric moisture regimes in most biogeoclimatic units, the major species throughout the region are fireweed, thimbleberry, and red raspberry. Following disturbance these species, particularly fireweed, can achieve densities and vigor that can threaten growing seedlings (see Case Study 4 in Appendix 1). Dense fireweed, in addition to competing for light, nutrients, and moisture, can kill conifer seedlings by snowpress in the fall and winter. It can also produce a mat which prevents soil warming in the spring. Fireweed is a threat when it attains very high cover values and heights of 1 m or more (for example, on untreated strips in Case Study 3 in Appendix 1). On some burned sites, thimbleberry, red raspberry, and trailing black currant (*Ribes laxiflorum*) may co-dominate with fireweed.

Reedgrass in the BWBS

Following disturbance in the BWBS, the grasses (primarily *Calamagrostis scribneri*) frequently invade and establish at high densities. This grass is present in varying quantities in the undisturbed forest as an understory species. Following canopy removal, either by fire or by logging, surviving reedgrass may be stimulated to prolific seed production and rhizome extension. If a seed bed is available, which may normally be the case after an intense wildfire or logging operation, reedgrass will be the first to claim the site and can attain virtual dominance (see for example Case Study 12, Appendix 1). It is tolerant of a range of ecological conditions, and can be found growing vigorously on subxeric to subhygric ecosystems. It is a major competing species in the Fort St. John and Dawson Creek Forest Districts.

3.4.2 Shrub complex

Definition

This community represents a later successional stage than the herb community, from which it develops, and can develop following wildfire or logging. By definition, the shrub complex consists mainly of shrubby vegetation with an average height of between 2 and 5 m.

Mesic to hygric sites

In mesic to hygric ecosystems, this complex is dominated by mixtures of shrubs and saplings of deciduous tree species. Mountain alder may form dense thickets in wetter sites, especially where mineral soil has been exposed. Other common species include willow, aspen, birch, poplar, and Sitka alder. Also present in many sites are black gooseberry (*Ribes lacustre*), red-osier dogwood (*Cornus sericea*) and high-bush cranberry (*Viburnum edule*).

Submesic to subxeric sites

The shrub complex on dry sites usually contains mixtures of willow, birch, poplar, or Sitka alder. Interspersed throughout this complex may be young aspen clones. Cover is usually discontinuous on drier sites; brush tends to be clumped.

Since fire on drier sites is normally more intense than on wetter sites, sprouting may be reduced or even eliminated following severe fires. Shrub invasion is mostly through seeding, which is a much slower process. On wetter sites, vegetation will advance to the shrub stage in a matter of 2-3 years, whereas on drier sites, it may require up to 10 years or more.

The main exception to this is aspen, if root systems of pre-existing individuals survive the conflagration. Where this happens, dense clones sprout (Fig. 9), commonly dominating the site completely (Case Study 1, Appendix 1).

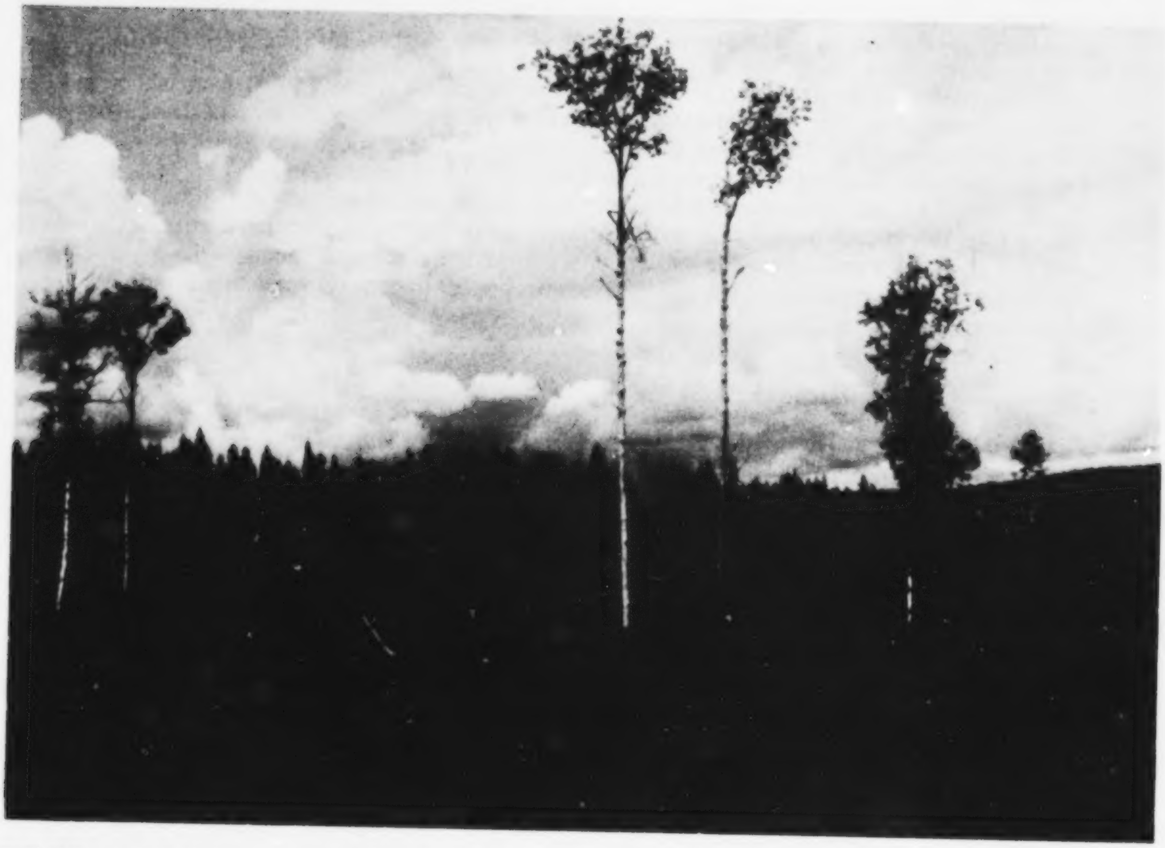


FIGURE 9. Aspen clones in the SBSe2 (01). Rehabilitation treatments must now deal with a high density of fast-growing aspen whips.

3.4.3 Pure aspen

Definition

Deciduous cover that is greater than 5 m tall and consists of at least 80% aspen is, in this classification, pure aspen. It can be found on old wildfire sites or on older clearcuts which now are classed as backlog NSR. The former may contain snags, which affect rehabilitation options.

Extent and development

Pure aspen is extensive in the study region on subxeric to subhygric sites. Aspen is a prominent member of post-burn seral stages in all biogeoclimatic units, with the exception of the SBSf and the southern portion of the k3 (C. DeLong, pers. comm.). It seems to be somewhat more abundant on south-facing slopes and on fine-textured soils in the SBS of the Prince Rupert Forest Region (Pojar *et al.* 1984). Its ability to produce pure or nearly pure stands is due to its sprouting action, which forms dense colonies of genetically identical individuals within each clone. Densities of up to 20 000-30 000 stems per hectare have been reported (W. Thorp, pers. comm.).

A pure aspen stand can be expected to exceed a height of 5 m in 5-15 years. Within clones, other deciduous species - such as willow, birch, or poplar - tend to be sparse. Pure aspen stands may be extremely dense initially, but as they develop, natural self-thinning creates a fairly evenly spaced mature stand. Gaps in the canopy are, of course, common and allow vigorous growth of understory shrubs.

Aspen is a short-lived tree and should be considered mature at about 55-90 years, although it can reportedly survive to the age of 200 (Haeussler and Coates 1986). At this stage, senescence may set in and aspen stands can begin to break apart. In the natural course of succession, spruce or subalpine fir form a suppressed - but continually growing - understory, which penetrates after 60-120 years, depending on the site conditions. Extensive areas of so-called pure aspen are partially stocked with understory spruce (Fig. 10). In such backlog stands, the advantages of clearing and starting from scratch must be weighed against the potential of the existing understory. As the conifers penetrate the aspen canopy, some whip damage may take place, but this does not appear to cause permanent damage (W. Thorp, pers. comm.).

Undergrowth in aspen stands (SBS)

Throughout most of the SBS zone, shrubs and herbs form the undergrowth, with patchy distribution corresponding to varying light levels beneath the canopy. Common species may include thimbleberry, black twinberry, grasses (e.g., *Calamagrostis* spp.), red-osier dogwood, prickly rose (*Rosa acicularis*), and high-bush cranberry. In natural gaps, red raspberry, fireweed, and willow may establish. Removing the overstory in rehabilitation sometimes stimulates the growth of these species, which then replace aspen as the main competitor for resources.

Undergrowth in aspen stands (BWBS)

In the BWBS zone, reedgrass is a common understory species in aspen forests. Due to its aggressive nature and ability to reproduce by both sexual and vegetative means, it is particularly difficult to control. The presence of reedgrass beneath an aspen canopy considerably complicates the rehabilitation of such stands.

3.4.4 Mixed deciduous

Definition

This backlog type consists of well-developed stands of deciduous trees at least 5 m tall, containing less than 80% aspen. Mixed deciduous stands may develop on old wildfire sites or on old logged openings. The former type may contain snags, especially if the wildfire took place less than 20 years ago and salvage logging was not complete.

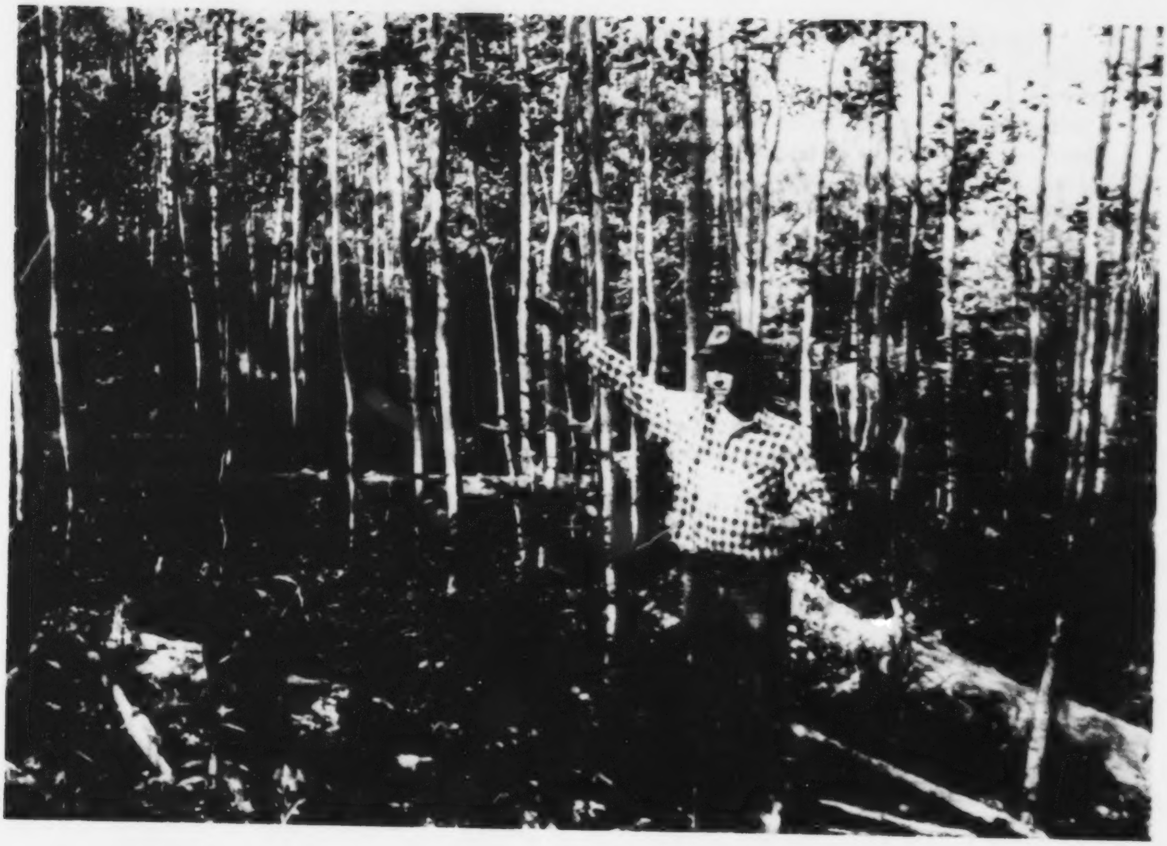


FIGURE 10. Spruce understory in the Mackenzie District (SBSo). Young aspen canopy still allows sufficient light penetration for fairly good spruce growth. Aerial spraying would release this understory.

Extent and development

Mixed deciduous forest commonly contains substantial amounts of either aspen or cottonwood (balsam poplar east of the Rockies). Paper birch is another common associate. Estimates of brush problems in the Prince George Forest Region,[2] for example, show that 85 220 ha on good and medium sites are dominated by cottonwood (including balsam poplar), with an additional 37 030 ha dominated by birch. These data include inventory classes "deciduous" and "deciduous/conifer," and are taken from the Prince George Forest Region as a whole, thus including ESSF and ICH zones.

On subhygric or hygric sites, willow and mountain alder may also form a part of the canopy. If Sitka alder exceeds 5 m, a mixed deciduous stand can be formed. In the SBS zone, however, Sitka alder rarely attains this stature.

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[2] Boateng, J. O. 1984. Estimates of forest brush problems in British Columbia. B.C. Min. For., Silv. Branch, Victoria, B.C.

This type differs from pure aspen mainly in that it is established partly from seed rather than from suckers. As a result, initial growth is not as rapid, and there is usually a delay in establishment following denudation (e.g., Case Study 3, Appendix 1). However, because these deciduous species can be prolific seeders, once they have established, high densities are possible. The relative proportion of the different species making up the type depends on the degree of mineral soil exposure and the presence of "seed trees" near the denuded site. Note that balsam poplar (*Populus balsamifera* ssp. *balsamifera*) may reproduce from both seed and sprouting (Coates and Haeussler 1986).

The main species constituting this type vary considerably in their growth and development. Cottonwood is generally faster growing than paper birch (Haeussler and Coates 1986), for example, and it is unlikely that the two species would be equally dominant on a site. Nearly pure cottonwood or balsam poplar stands do occur, mostly on alluvial sites, although birch may be present as scattered clumps or individuals. By definition, aspen may account for up to 80% of a mixed deciduous stand. Where it dominates, other deciduous species occupy gaps or other openings in the canopy. Under some conditions, such as following an intense wildfire, willow species may invade first and dominate the mixed deciduous complex. An example of this can be seen in parts of the Grove Fire near Prince George.

Understory conifers

Some mixed deciduous backlog types may contain a significant stocking of acceptable crop trees (400-700 stems per hectare) beneath the deciduous canopy. The presence of this understory clearly affects rehabilitation choices. If the understory spruce is well established, then rehabilitation is best directed at a conifer-release operation, rather than at a brush-clearing operation. In those biogeoclimatic units where subalpine fir is deemed to be an acceptable species, it should contribute to the stocking criterion given above.

3.4.5 Overstocked pine

This backlog type consists of pure lodgepole pine stands in which estimated "initial" density is greater than about 10 000 stems per hectare. Overstocked pine generally results from wildfire, but may also develop after logging, especially in parts of the SBSa subzone in the Cariboo Forest Region (O. Steen, pers. comm.).

If the overstocked stand is less than about 15 years old, and if the height of the dominant trees is less than about 2 m, then juvenile spacing remains a potential alternative to rehabilitation.

3.4.6 Stagnant pine

After the age of about 15 years, or a height of about 2 m, spacing becomes silviculturally inappropriate.[3] Therefore, this backlog type does not carry a spacing option, and rehabilitation by knockdown or burning is a realistic option for bringing that forest land back into production.

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[3] Goudie, J. W. 1980. The effects of density on the growth and development of repressed lodgepole pine and suppressed Douglas-fir. Final Rep. on EP 850.2. B.C. For. Serv., Res. Br., Victoria, B.C. Unpubl. ms.

3.4.7 Deciduous/conifer

Definition

This type is an admixture of deciduous and coniferous trees, both of which are present in the canopy. It can follow old wildfires or I.U. logging.

Old wildfires

Deciduous/conifer vegetation types following old wildfires consist of suppressed spruce or subalpine fir in the process of emerging through the deciduous canopy. The age at which this takes place depends on many factors. Given the relatively slow growth of spruce under aspen (Steneker 1967), at least 60-80 years would elapse before suppressed understory conifers could penetrate a deciduous canopy.

Diameter logging

This backlog type is associated with a specific type of I.U. logging. It has a higher stocking rate with respect to conifers than other backlog types, but it is concentrated in subalpine fir (much of which may have been injured during logging) and immature (possibly inferior) spruce. The deciduous vegetation in this type is generally between 15 and 30 years old, and therefore has developed into tree form.

Strip logging

This type differs from other I.U.-logged stands in that partly stocked and clearcut strips of lands are arranged parallel to each other. Rehabilitation of this type is distinguished by the need to concentrate activities in the unstocked portion of these sites. The presence of partially stocked strips affects rehabilitation options: if prescribed fire is the preferred choice, then the stocked strips need to be felled, either for merchantable timber or for fuel distribution to prepare for a burn. The nature of the brush within the unstocked portion is highly variable, depending on the same factors listed under diameter-logged stands. Aspen, birch, cottonwood, or balsam poplar are probably the most common deciduous species within this type.

4 BRUSH CLEARANCE

4.1 Introduction

Rehabilitation of backlog lands involves the clearing or setting back of existing vegetation, normally followed by treatments designed to prepare planting microsites. It includes a wide array of methods, which can be applied to an assortment of backlog types. This section reports on existing brush-clearing methods and, where evidence exists, their relative success or failure. Many of these methods have only recently been introduced and are continually changing, making assessment of treatment effectiveness difficult.

Five groupings of backlog vegetation types can be associated with five rehabilitation types in the northern Interior:

1. hardwood conversion (pure aspen, mixed deciduous);
2. wildfires (herb and shrub complexes and deciduous/conifer, usually with snags);
3. overstocked pine (overstocked and stagnant pine);
4. recently failed openings (herb and shrub complexes); and
5. old logged openings (deciduous/conifer).

Brush clearance techniques include mechanical knockdown, manual clearing, chemical treatments, prescribed fire, or V-plows.

4.2 Hardwood Conversion (pure aspen and mixed deciduous)

Hardwood stand conversion is a rehabilitation objective throughout the study area, but nowhere is it as extensive as in the BWBS zone. It has been estimated that about 414 000 ha in the Peace TSA and a further 525 000 ha in the Fort Nelson TSA are dominated by aspen (Boateng 1984). However, since the recent introduction of a mill using aspen in Dawson Creek, the status of hardwood conversion in the BWBS as a rehabilitation objective has changed substantially. The rehabilitation of mixed deciduous stands has now become a more important focus in silvicultural plans.

Problems with conversion are confounded by an equally serious problem of competition from reedgrass, which is present in most, if not all, aspen stands. When an aspen overstory is removed, reedgrass beneath is stimulated by higher light and temperature levels, and a new problem replaces the old one.

Hardwood stand conversion in the SBS has focussed largely on aspen and mixed deciduous stands of a relatively immature stage, mostly less than about 40 years old. Many of the hardwood stands in the Prince George SBS contain understory spruce which would probably release if the hardwood canopy were removed. Over much of the SBS, the normal course of succession consists of early establishment of aspen or other hardwood, with spruce and perhaps subalpine fir eventually gaining dominance (eg: Draper and Hamilton 1984).

4.2.1 Machine clearing

In the BWBS, winter shearing, then piling or windrowing is the customary procedure for clearing a site.

In his experimental trials at Stewart Lake, west of Dawson Creek, L. Herring has demonstrated the increase in brush competition following winter clearing, unlike that after fall clearing. Superior brush control associated with fall treatment is attributed to underground suckers in aspen being cut during the operation of the brush blade. However, even where the brush blade made a drastic impact, freedom from competing vegetation is short-lived. Where reedgrass is a component of the stand, knockdown and brushblading, if not thorough, can lead to increased competition. Case Study 12 (Appendix 1) is a rehabilitation site that was windrowed in winter, which did not achieve effective brush control.

Shearing is carried out with a shearing blade mounted on a powerful crawler tractor, commonly of D-8 size. The technique is believed to be most effective in winter, when the ground is frozen and stems are brittle. At this time, most stems of snags and deciduous trees are snapped off near the base. Larger trees are more likely to be uprooted when clearing is carried out in the fall. Winter shearing tends not to uproot trees. Residual stubs, if not killed, may sprout vigorously, thereby aggravating a brush problem. Several respondents indicated that herbicide applications are necessary following winter knockdown. Fall clearing is a more drastic treatment, which does provide some brush control, if only for one season (W. Thorp, pers. comm.).

In the Mackenzie Forest District, B.C. Forest Products has used a Rhome side-cutter blade mounted on a D-8 crawler to treat mature aspen with stem diameters up to 50 cm and densities up to 250 stems per hectare (J. Zak 1986).

Windrowing or bunch-piling

Conventional windrowing, or bunch-piling, usually follows or takes place concurrently with shearing. A brush blade is used, which may or may not result in mineral soil exposure and a degree of brush control. Winter operations, while effective for shearing, do not allow much mineral soil exposure and tend not to disturb the surface organic material. Windrowing is discussed more fully in Section 5.3.2.4.

Marden duplex drum chopper

The Marden duplex drum chopper has been used on occasion, but few silviculturists in the area had much experience with it. West of the Rockies, the Marden has been used mostly for pine rehabilitation (Section 4.4). At Stewart Lake in the BWBS, it was found to be less effective than conventional clearing techniques (W. Thorp, pers. comm.). The Marden is best only when temperatures are below about -10°C, the ground is frozen, and the snow is not deep. If these conditions are not met, aspen tends to spring up behind the drums.

4.2.2 Chemical treatment

Aerial spraying

Although an effective means of killing hardwood overstories, aerial spraying is restricted by perceptions of complications in the permit application system and lack of experience, according to qestionnaire response. The lead time necessary for permit approval is generally about 6-8 weeks, but can be longer in complex cases, especially if the approval is appealed. Some permit applications fail to gain approval because of conflicts with Fish and Wildlife Branch objectives.

Aerial applications of glyphosate have been shown to be effective against overstory aspen and balsam poplar at Stewart Lake (L. Herring, pers. comm.). In one trial, glyphosate was applied at the rate of 2.8 kg a.i./ha, from a boom spray system mounted on a helicopter. (Note that this is greater than the operational maximum rate of 2.1 kg a.i./ha.) Overstory trees were defoliated and suckering was minimal. However, understory aspen, poplar, and willow were less effectively treated and produced suckering in subsequent years. Worse, reedgrass was not controlled and dominated the site soon after treatment.

Aerial herbicide treatments have had mixed success in hardwood conversion because of their failure to control understory vegetation (W. Thorp, pers. comm.). The use of finer droplets may allow greater penetration through the hardwood canopy, thereby controlling understory competitors (J. Boateng, pers. comm.). Use of finer droplets, however, must be weighed against the greater potential for drift.

The main environmental constraint is proximity to watercourses, about which a 10-m pesticide-free zone (PFZ) must be maintained. For aerial application, a considerable drift buffer zone must also be planned, so aerial spraying normally does not take place within about 100 m of a watercourse or standing body of water. In the Prince Rupert Forest Region, spraying can approach 30 m of a watercourse, if a card line is laid and windspeed and direction are favorable (F. Newhouse, pers. comm.). Since a disproportionate number of backlog sites are located in subhygric to hygric ecosystems which are associated with standing or running water, environmental constraints can impose major limitations to the use of herbicides. However, these constraints also apply to mechanical brush clearance.

The aerial application of hexazinone "gridballs" has also been tried at Stewart Lake, with impressive results: the balls, applied from a helicopter at the rate of 4.0 kg a.i./ha, penetrated through the aspen canopy to the ground, and were effective against reedgrass, willow, and aspen. Gridballs were not registered for general forestry use, but were used only under special research permit. It is anticipated that another pelletized form of hexazinone (pronone) will be registered for forestry use in the future (e.g., Sutton 1986). Herbicide screening trials for reedgrass and aspen are currently being carried out by L. Herring under FRDA Project 1.3.

Timing

Silviculturists do not agree on the optimum time of treatment. Most aerial applications take place between mid-July and early September. In Ontario, Sutton (1984a), using a mist-blower on young aspen sprouts, found summer applications of both glyphosate and hexazinone to be more effective against aspen than fall applications. Exposure of actively growing conifers to glyphosate may result in damage, although the extent and degree appear to be variable (Sutton 1984a). Early fall applications are also believed to be effective (B.C. MOFL 1987). Rain, falling within 6-12 hours after spraying, will limit the effectiveness of aerially applied glyphosate. On the other hand, if target trees are experiencing moisture stress, mortality and control of root suckering may be restricted. Glyphosate is used far more than 2,4-D, despite its greater cost, because of perceived superiority in effectiveness, especially in controlling aspen suckering (F. Gunderson, pers. comm.). Application rates for hardwood conversion are normally set near the maximum operational rate suggested by the manufacturer, namely about 2.1 kg a.i./ha (6 L/ha).

Planting

Prompt planting following aerial spraying of immature deciduous canopies has been reported as being successful in the Mackenzie Forest District (D. Greenley, pers. comm.). If understory control has not been effected, a second herbicide application will be necessary. Planting beneath mature hardwoods that have been chemically treated may not be feasible because of the potential hazard of falling stems and branches.

Ground Injection

Ground injection of the soil-active herbicide hexazinone has been used sparingly as a rehabilitation measure. It received temporary registration in Canada only in 1984. Depending on the nature of vegetation, it has been applied on a grid pattern, with spot applications usually spaced at 1.5- to 4-m intervals. It can also be applied selectively at the base of competing trees or shrubs. Hexazinone application has best results during cool, wet days, during which percolating rainwater will transmit the chemical into the soil. Once in the soil, conditions must be such that hexazinone can translocate into the roots. Since it may damage crop trees, it cannot be applied close to them. The manufacturer has recommended that injections or ground-spraying be more than 1 m from a crop tree stem.

Spot gun

Hexazinone is normally applied using a spot gun, with which a specified dosage is squirted onto the surface of duff or exposed mineral soil. The efficacy of this treatment seems to diminish with increasing duff thickness. In the Prince Rupert Forest Region, it has been recommended that sites containing duff thicker than 15 cm be screefed before spot gun application; otherwise, a "spear" should be used (Geissler and Newhouse 1987). In the Mackenzie Forest District, a "screef and squirt" technique is used to apply hexazinone in areas of thick duff (J. Zak, pers. comm.). Caulk boots are used to make the screef.

Spear

The spear consists of a sharp cone-shaped nozzle at the end of a metre-long tube, through which hexazinone can be applied. The spear can penetrate the duff layer and deliver the herbicide directly to the mineral soil surface. Herbs and shrubs which confine their rooting to the duff layer may not be affected by ground-injected hexazinone (Geissler and Newhouse 1987).

Movement of hexazinone

Once it has reached the mineral soil, hexazinone is relatively mobile and has the potential, under certain conditions, to move out of the treatment area. In the Prince Rupert Forest Region, it has been observed in a few instances to move more than 50 m (Geissler and Newhouse 1987). Conditions favoring overland flow, such as compacted skidtrails, frozen soil, ditches or natural channels, may promote off-site movement. In medium textured soils, such as silty loams, hexazinone leaching may be too slow to threaten groundwater quality (Feng 1987). In contrast, sites with a high water table or coarse textured soils with a potential for saturation may be poor candidates for hexazinone application because of the risk of groundwater contamination.

Disadvantages

The major disadvantage to the use of herbicides to kill hardwood overstories is that the snags created become a serious hazard to silvicultural crews for many years, until they fall down naturally. Control of understory vegetation has also been a problem.

Stem injection

Stem injection treatments (such as "hack and squirt") are used to rehabilitate aspen or mixed hardwood stands. They are also extensively used in conifer release and pre-harvest brushing, where deciduous trees are overtopping or co-dominating a spruce stand, respectively.

A primary objective of aspen rehabilitation is to prevent resprouting once the canopy is cleared. If stem injection of mature aspen precedes harvesting or mechanical clearing by a sufficient time period, the injected glyphosate will have time to translocate to the roots, thus inhibiting sprouting (F. Gunderson, pers. comm.). Although top-kill and leaf area reduction is soon apparent following injection, a lead time of at least 3 years is probably needed for effective root kill (B. Zak, pers. comm.).

Stem injection for site preparation and weed seed tree control is more intensively practiced in the SBS of the Prince George Forest Region than elsewhere in British Columbia. In 1986, nearly 6800 ha were treated using stem injections of glyphosate (Humphries 1987). About 90% of this total was concentrated in the Mackenzie Forest District, reflecting an aggressive program undertaken by B.C. Forest Products.

Methods

Hack and squirt is the most common form of tree injection. It entails the cutting of a notch or frill with a downward stroke of an axe or hatchet, followed by a squirt of herbicide (usually glyphosate) into the notch. The dosage and number of notches per stem are regulated by stem diameter and the chemical used.[4] Advantages of the hack and squirt technique include the simplicity (and thus reliability) of the equipment and its use. It can be used year round, if mixed with antifreeze during cold snaps (F. Gunderson, pers. comm.).

Other techniques include a "hypohatchet", in which the herbicide is delivered through a small tube into the cutting blade of the hatchet. The chemical is applied in a single motion. In some cases, the delivery channel may clog with wood splinters, and there is a potential for splashing if chemical remains on the blade from a previous cut (Bancroft 1987).

The "injection lance" has been developed by the Silviculture and Research Branches of the B.C. Ministry of Forests and Lands (Gilmour 1984). It consists of a 1.8 m lance with an injection head which releases herbicide when it is jabbed against a tree. Like the hypohatchet, the injection lance allows stem treatment in a single movement. However, its weight and cost are potential disadvantages (Henigman and Beardsley 1985). In the Mackenzie Forest District, B.C. Forest Products uses a punch and fill technique to inject glyphosate into residual hardwood stems. Fewer accidents have been reported using this injector method than with other methods employing a hatchet (J. Zak, pers. comm.).

The "Dillistone Weed-Do Injector" has been used on a trial basis in the northern Interior. This implement injects a 0.22-inch cartridge filled with herbicide and a solidifying agent into the tree. The number of cartridges per tree (dosage) depends on the stem diameter and the chemical used.[4] The advantages of this technique are that it can be used even in heavy rain, and it appears to be relatively safe with little chance of worker contact. On the other hand, the technique does not adequately mark treated stems, resulting in a high chance of missed or over-treated stems.

Cut-stump treatments

"Cut-stump" treatments are used in the rehabilitation of immature deciduous stands in which manual brushing would lead to excessive coppicing. Target species are commonly birch, alder and willow. The treatment involves severing a stem near to the ground with a brush or clearing saw, followed by prompt application of a measured dose of herbicide, usually applied with a spray bottle. Combined "brush saw herbicide applicators" are available, which sever the stem and apply a measured dose of herbicide in one operation. In the Mackenzie Forest District, this equipment has been used on aspen and other deciduous species with stem diameters between 5 and 15 cm (J. Zak, pers. comm.). In preliminary trials it has also been successful against Sitka alder in the Vanderhoof Forest District (SBSd) (B. Walker, pers. comm.).

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[4] Bancroft, B. G. 1987. Brush control: a cost effectiveness analysis for conifer release from red alder. Nat. Resources Manage. Prog. Rep. No. 50, Simon Fraser Univ., Vancouver, B.C. Unpubl. ms.

Disadvantages of the cut-stump technique include potential exposure of workers in their knee to ankle zone and, in the case of the brush saw/herbicide applicators, the difficulty of finding experienced and competent contractors (J. Henigman, pers. comm.).

Combination treatments

In addition to their use in hardwood conversion or brush clearing, chemical treatments have been tested as secondary treatments, either alone or in combination with second-pass mechanical treatments. Experimental plots at Stewart Lake indicate that pre-treatment with hexazinone provided effective control of reedgrass and hardwood suckering. Glyphosate was found to be less effective than hexazinone against reedgrass. The use of aerially applied glyphosate, in combination with mechanical treatments, is the subject of an ongoing research effort, part of which is being carried out at Stewart Lake (FRDA Projects 1.2 and 1.3, both led by L. Herring).

4.2.3 Prescribed fire

At Stewart Lake in the Dawson Creek Forest District, prescribed fire on untreated brush and on chemically treated brush has been tested. The site had been subjected to a number of wildfires in the past and, at the time of the trial, supported dense aspen and balsam poplar, as well as reedgrass. Part of the site was treated with 2.8 kg a.i./ha of glyphosate in June 1983. The following year in May, the site was broadcast-burned. The browned area received a higher ground impact, and poplar suckering was effectively controlled; reedgrass, however, recovered almost immediately and dominated the site. The part of the site not pretreated by glyphosate sustained a low ground impact, and poplar suckering was not controlled. Because of the tolerance of reedgrass (and, in the absence of glyphosate, poplar) to fire, it does not seem to be an effective rehabilitation treatment except as a clearing operation to facilitate secondary mechanical treatment (L. Herring, pers. comm.). Higher burn impacts may be more effective.

Operationally, there are two options for the use of prescribed fire in rehabilitation:

1. machine knockdown followed by broadcast burning, or

2. brown and burn.

If enough fuel is present on the block after knockdown is completed, a broadcast burn may be prescribed. Fuel loading depends on the composition and structure of the backlog stand. The decision of whether to broadcast burn or not depends also on the desired impact. If a secondary treatment is envisaged, then a high impact is not necessary, and it will suffice to prescribe a fire that will consume much of the fine fuel, but not the duff. On the other hand, if the broadcast burn constitutes the final treatment before planting, then burn impacts must be high enough to consume part of the duff layer and set back competing vegetation. High impact burns have been considered necessary in subhygric to hygric ecosystems in the past.

Distribution of fuel loadings are also a factor for consideration: many backlog stands exhibit a clumped pattern of hardwood trees and shrubs. This complex, after having been knocked down, may not provide a slash cover sufficiently continuous to carry a broadcast burn. The composition of a hardwood stand has a bearing on the efficacy of the burn. For example, birch is widely believed to have a lower moisture content than aspen or cottonwood, and therefore will be more effective in carrying a broadcast burn (T. Calhoun, pers. comm.). Alternatively, a birch stand may require a shorter drying period than a poplar stand, after knockdown.

Timing of prescribed fire

The timing of the fire may be set using the prescribed fire predictor (Muraro 1975), but burning knocked-down backlog hardwood stands is still outside of the experience of most silviculturists. Early summer knockdown, followed by fall broadcast burning, would be an ideal sequence if moisture levels of the fuel drop to an appropriate level. Deciduous slash is believed to be more difficult to burn than regular logging slash, because of the relative paucity of fine fuels (B. Hawkes, pers. comm.). A minimum of several months is probably necessary to allow sufficient drying. Throughout the wetter units of the SBS, the average number of ignition days is very low after the end of August, and the chance of having a successful burn consequently diminishes (Vihnanek and Feller 1985). Overwintering of the slash would tend to compress it and this, together with invading herbaceous and shrubby brush, may result in a less intense fire than desired. Backlog sites receiving lower impact fires will generally need to be treated again, either mechanically or chemically.

4.3 Wildfire Rehabilitation

In the BWBS, the Osborne Fire, located about 50 km northwest of Fort St. John, is an example of wildfire rehabilitation. Case Study 12 (Appendix 1) examines the status of seedling performance in one part of this fire.

Rehabilitation was initiated promptly on this site. During the winter after the fire, knockdown and windrowing cleared snags. In the spring, rows were burned. Bracke mounding was a secondary treatment on the cleared site. Spruce plugs were spring-planted in 1985.

Knockdown and clearing are usually more efficient and cleaner in the winter than in the summer or fall (as less soil is moved into the piles or rows), but because the roots of competing vegetation are left intact, the site is quickly dominated by reedgrass and aspen (see also FRDA Project 1.2). This usually necessitates chemical treatment, applied either before planting (hexazinone ground-injection) or after planting (glyphosate backpack or aerial spray). Despite summer or fall piling being more drastic and exposing mineral soil, immediate planting without further mechanical, chemical or combination treatments has little chance of success in the face of potentially severe competition from aspen and reedgrass.

Reedgrass is a major problem in wildfire rehabilitation in the BWBS zone. The Osborne Fire showed that this grass can attain consistently high covers with average heights over 50 cm in only 2 years. Such severe competition allows little respite for seedlings planted in small patches or ripper plow berms. Either more drastic treatments, which effectively set back competing vegetation from a larger area (such as moldboard plows or discs), or chemical treatments are required to give seedlings breathing room. Even moldboard plows and discs may not bury reedgrass sufficiently to prevent resprouting (W. Thorp, pers. comm.).

Examples of wildfire rehabilitation in the SBS zone include the Paul and Swiss fires in the Morice (Houston) District. The Paul Fire took place in 1961, destroying about 8000 ha of forest; the Swiss Fire took place in 1983, destroying 18 000 ha.

Snag falling

The presence of snags is the distinguishing characteristic of this disturbance type. These are removed as a first step in rehabilitation, either by cabling or blade knockdown. On recent fires, especially if they are reasonably accessible, snags are made available for salvage logging or firewood collection before rehabilitation commences.

Snag falling is frequently a prerequisite to secondary treatment and planting, especially in older fires. As snags are weakened by age, insects and rot, they become an increasing hazard to planters. In the Paul Fire, planting under snags was allowed in small areas where mechanical knockdown was precluded by the sites' sensitivity to heavy traffic. Snags deemed hazardous (for example, those leaning or deeply burned) were felled by chain saw.

Snag falling is commonly accomplished by a bulldozer equipped with a piling blade, or by cabling with an anchor chain between two heavy crawlers.

Cabling

Cabling may be as cost effective as shearing with a blade. In the Paul Fire, cabling had the advantage of aligning slash, thereby facilitating windrowing. On the other hand, the difficulty of coordinating two machines was cited as a disadvantage (I. Lister, pers. comm.). According to some questionnaire respondents, cabling is falling out of favor because of expense, the high level of operator skill required, and the excessive damage to the ground. Effectiveness and soil disturbance are heavily dependent on operator skill and/or degree of supervision.

Powerful prime movers (D-8 or larger) are needed to knock down snags, especially on recent wildfire sites, since root systems are still intact and stems are not yet weakened by rot. Clean shearing of stems is preferred, to keep stumps (and soil) on the site and to allow a tighter windrow or pile.

Knockdown is then immediately followed by windrowing or piling. Burning of windrows or piles is subject to the policy of the district office.

Rehabilitation options

Once the slash has been piled and burned, two options may be followed. One is to plant immediately with large stock. This is the preferred option if brush hazard is not high, and ground disturbance has created planting spots. If the site is brush-prone, an aerial herbicide treatment is planned, with planting carried out as soon after as possible. A possible sequence in this case would be:

1. knockdown and windrow in winter;

2. burn the rows the following fall; and

3. aerial herbicide in June or early July, then plant with "hot-lifted" stock (F. Newhouse, pers. comm.).

Thus, the time elapsed between initiating rehabilitation and planting is about 18 months.

Rehabilitation plans are usually preceded by a careful stratification of the area to be treated. Inoperable areas are identified and marked for alternative treatment, either brown and burn, aerial herbicide alone, and/or fill-in planting, if partial stocking is present.

4.4 Overstocked Pine

Rehabilitation of wildfires which have naturally regenerated to overstocked stands of pine is a problem particularly in the SBS zone. In the Lakes Forest District, for example, there are an estimated 86 000 ha of overstocked pine, aged 40-60 years (Blackwell *et al.* 1986).

Wildfire in live lodgepole pine stands often kill the trees but not the seed within attached cones. The heat of the fire opens the resin bonds of the cones, allowing viable seed to escape. If sufficient mineral soil has been exposed by the fire, which is normally the case in these drier areas where duff layers are thin, a very high density (from 50 000 to 500 000 stems per hectare) of pine seedlings can become established. The result is an overstocked stand of young pine beneath standing snags.

Timing

Depending on the age, density and site quality, individual trees may experience repression from an early age. Volume and height increment can therefore be significantly different from the site potential. In general, it is believed that the older the stand, the greater the loss in volume - which cannot be regained. Furthermore, the ability of the trees to experience height growth release is diminished. Studies by Goudie indicate that release at age 18 or greater yielded an immediate response in diameter, but response in height increment was delayed significantly or was non-existent.[5] Release at age 11, however, yielded a response in height growth. Overstocked pine stands therefore have to be treated early if a satisfactory volume is expected over a reasonable rotation period.

It is generally perceived that overstocked pine must be treated before 15 years has elapsed, although if a biologically relevant threshold age exists it is probably stand- and site-specific. Juvenile spacing comes under the category of "stand tending," rather than "rehabilitation," but different methods and their effectiveness need to be considered in deciding whether to rehabilitate by knockdown or burning, or to tend by spacing.

Spacing

Juvenile spacing is normally carried out manually with brush saws, shears or clippers. Shears and clippers are effective in high density stands in which stems are less than 5 cm diameter (B.C. MOFL 1984). Chain saws are considered unwieldy in dense stands, and therefore uneconomical. Conventional juvenile spacing of dense stands requires mechanical strip thinning as a prerequisite, to allow access into the stand. Falling of snags or residuals normally precedes spacing operations, primarily for safety reasons. Target spacing is set by the Regional Stand Tending Guidelines.

Strip spacing, using a flailing device attached to a skidder, has been tested on one overstocked pine stand in the Vanderhoof Forest District. This technique cleared strips about 2.5 m wide, leaving approximately 3 m leave-strips. The intent was to release trees along the edges of the strips, and facilitate access for manual spacing of trees within the leave-strips. Unfortunately, either the spacing was left too late, or site quality was inadequate to allow a response, because no height response was observed (Fig. 11).

Many silviculturists in the SBS zone agree that spacing pine stands less than 12-15 years old is an economically viable alternative to rehabilitation, if funding and time are available. The choice of spacing or knockdown depends on biological and economic factors. The presence of a significant subalpine fir component in the stand (for example, in the SBSe2) may tip the balance in favor of knockdown (J. Casteel, pers. comm.). Dense snags may render spacing too expensive, in addition to creating an excessive fire hazard once they have fallen.

In parts of the SBSe2, and certainly in the SBSj and f subzones, spacing may lead to snow breakage. Spindly juvenile pine is especially vulnerable (B. Williams, pers. comm.). In the SBSk2 and k3, and throughout the SBSd, snow loadings are generally not heavy enough to cause significant damage (B. Walker, pers. comm.).

A number of interviewees stated that because funds for spacing programs are seriously limited, many pine stands are allowed to attain a stagnant condition, at which point there is no alternative to knockdown (J. Casteel, pers. comm.). On the other hand, spacing programs are often suitable projects for federal employment projects.

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[5] Goudie, 1980.

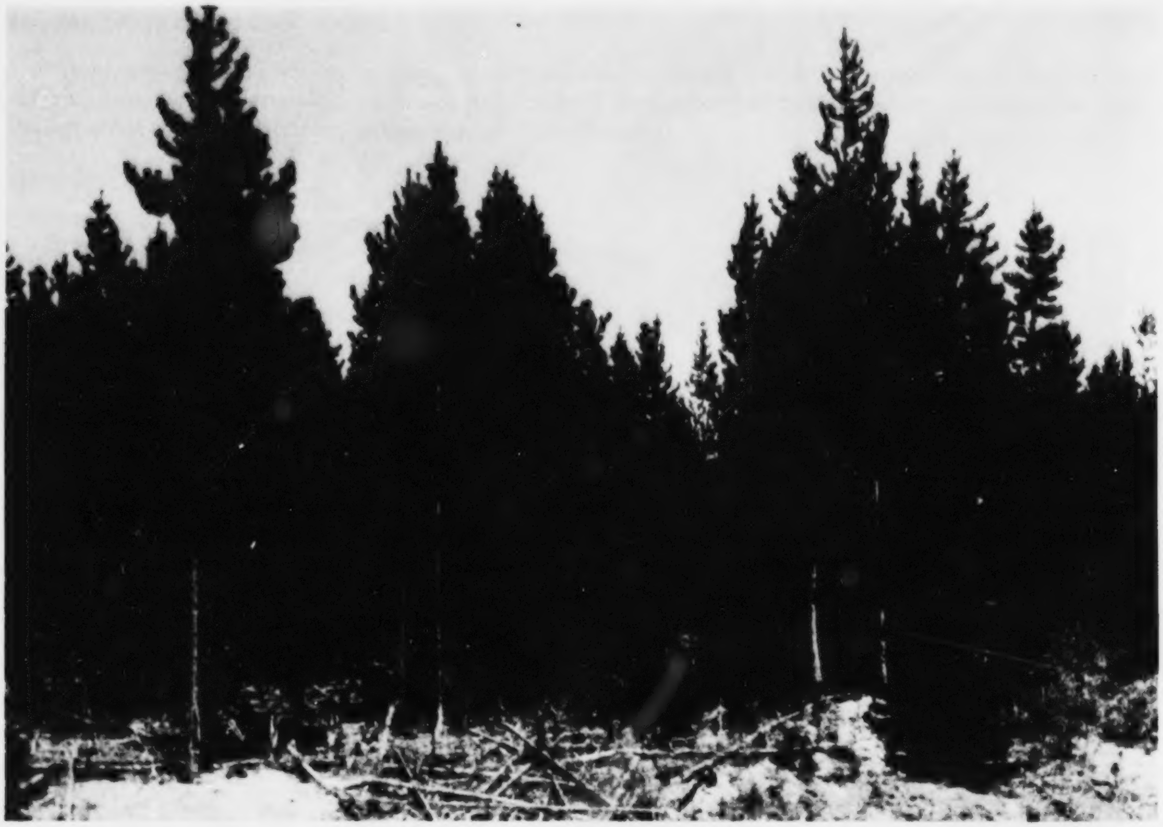

FIGURE 11. Pine strip-spacing in the Vanderhoof Forest District (SBSi). This technique is potentially useful for allowing access for hand spacing, but in this case no further treatment was applied. Virtually no diameter or height release was apparent.

Shearing and windrowing

Probably the most common rehabilitative treatment is winter shearing followed by piling or windrowing. It is accomplished with a straight angling blade mounted on a powerful crawler, usually D-8 or D-9 size.

Shearing is most effective in winter when the ground is frozen and stems are brittle. When this operation is carried out under mild conditions, stems may flex beneath the blade as it passes, only to spring up afterwards. The remaining stubs pose a problem to subsequent treatment or planting. It has been reported that ambient temperatures lower than about -10°C are needed for effective shearing (D. van Dolah, pers. comm.). Piling is difficult when snow depths are greater than about 50 cm. Winter operations in the Vanderhoof Forest District, however, have the advantage in that contractors with the necessary heavy-duty equipment are available. These individuals are busy with agricultural land-clearing in non-winter months so that contract bids are competitive, with costs in the range of $250-300/ha (not including windrow burning) (D. van Dolah, pers. comm.).

Windrows are burned the following fall. Because brush competition is usually not severe in lodgepole pine sites, the site can be planted in the subsequent year. Frequently, rehabilitated blocks will contain portions of subhygric or hygric sites, including depressions, gullies or draws (Fig. 12). These areas can be planted to large stock spruce (for example PSB 415), but, without special treatment (such as mounding), survival is usually poor.

FIGURE 12. Rehabilitation of overstocked pine in the Vanderhoof Forest District (Long Lake). Rehabilitated sites are frequently mosaics of mesic (01) and subhygric to hygric (07 - 08) ecosystems. Note "stubs" remaining after shearing took place in mild conditions.

Prescribed burning

Prescribed broadcast burning following knockdown is another option. Knockdown and burn being investigated in FRDA Project 1.13 (Blackwell *et al.* 1986) has been found to be cheaper than knockdown and windrowing, because of lower preparation and mop-up costs. Knockdown for the broadcast burn treatment was carried out in September 1985, with burning taking place the following spring and summer. Impact of the burns ranged from "low" (late May) to "high" (late July), corresponding to the curing of the slash and the prevailing weather conditions.

Goudie has suggested that, if feasible, burning a live pine stand at some point after it has developed a cone crop, but before an age of about 25 years, may be a viable option.[6] Secondary stands developing from early burns are believed to be more widely spaced than the original.[7] Although control may be an important consideration, the costs of this option could be well below that of mechanical knockdown.

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[6] Ibid.

[7] Ibid.

Marden brush chopper

The Marden brush chopper has been used to rehabilitate stagnant pine. This equipment is restricted to smooth, level terrain, otherwise the drums will ride over obstructions such as rocks and stumps. Also, the implement is unwieldy, with high power requirements (Breadon 1987).

Resource conflicts

Land-use conflicts with Fish and Wildlife Branch may be encountered on pine rehabilitation sites. Overstocked pine stands are a natural part of the forest, and certain species, such as snowshoe hare, favor them for shelter and hiding cover. At the same time, hares may cause unacceptable levels of damage in young lodgepole pine stands, thus constituting a silvicultural problem in certain areas (Sullivan 1984).

4.5 Recently Failed Logged Openings (Herb and Shrub Complexes)

The rehabilitation of logged openings which have failed to restock within about 10 years is an important activity in both the Prince George (M. Bruhm, pers. comm.) and Prince Rupert (F. Newhouse, pers. comm.) forest regions. Clearing early seral vegetation of herbs and shrubs is the objective in this disturbance type, and thus a separate brush clearance operation is not always required. Common treatments involve the use of herbicide sprays, brown and burn, and V-plows. Machine clearing and piling may be used on older sites dominated by hardwoods, such as alder, aspen and cottonwood. Rehabilitation of sites carrying hardwood stands greater than 5 m tall is discussed under "hardwood conversion" (Section 4.2).

Sitka alder

Sitka alder is an important brush species on backlog sites in the SBS zones. It can occur as nearly pure stands, in the form of dense thickets, or interspersed with pine or spruce. Some silviculturists view low density alder as a favorable component within a growing plantation, as crop tree growth is believed to benefit from the additional nitrogen fixed by the alders' root nodules (C. von Hahn, pers. comm.). This is corroborated on one site by Ballard (1984), who observed that leader length of spruce was 50% greater on scalped sites in which alder had invaded, than on sites which were alder free. However, when alder cover reaches a certain threshold cover, competition for light, nutrients and moisture probably begins to compensate for any benefit accrued.

4.5.1 Chemical treatments

The effectiveness of herbicides in controlling early seral vegetation is still inadequately studied. Trials conducted by L. Herring in the Bowron River valley east of Prince George (SBSf) suggest that the effectiveness of chemical applications may be short-lived, in part because affected weed species may quickly be replaced by others (C. DeLong, pers. comm.).

Aerial

In Case Study 13 (Appendix 1), an aerial application of glyphosate was used to clear brush on a failed plantation of spruce in the BWBSd2 unit in the Fort St. John District (Fig. 13). Spraying was applied in August 1985, with fill-in planting following in 1986. The spray was effective against reedgrass, aspen and several other species such as rose (*Rosa acicularis*) and fireweed, but only partly effective against Sitka alder. Surviving spruce seedlings were unaffected by the spray, but residual subalpine fir experienced leader die-back. The dead grass mat was more than 10 cm thick in places and required aggressive screefing while planting. Remote sites such as this may not be economically treated by specialized equipment in a second pass operation. One alternative now being tested in the Fort St. John Forest District is a hand-held power scalper (the "Hawk Power Scalper"), which may provide effective spot screefing.

FIGURE 13. Aerial spraying in the Fort St. John Forest District (BWBSd2). The spraying was very effective against reedgrass. Raw fill-in planting was prescribed, but requires rigorous screefing of the dead grass mat (Case Study 13, Appendix 1).

Backlog sites occupied by Sitka alder ("shrub complex") can also be cleared with the use of chemicals. In the Vanderhoof Forest District, for example, 2,4-D, with diesel as a surfactant, was applied to alder brushfields (C. von Hahn, pers. comm.). This chemical is believed to be less effective than glyphosate against most species, but appears to be more effective against alder, willow and birch (Haeussler and Coates 1986). It is also cheaper.

Manual brushing of alder is seen as ineffective because of the rapid rate of coppicing from stem collars (B. Walker, pers. comm.). However, this can be eliminated by using a brush saw with a spray attachment, which adds herbicide onto the cut stem (cut-stump treatment, discussed under "Hardwood Conversion"). Operationally this has not been extensively tested in the northern Interior, but preliminary trials suggest that it is expensive and ineffective on small diameter stumps (J. Perry, pers. comm.), such as those which may be expected on recently failed logged openings. Stems less than about 5 cm in diameter tend to whip away from the saw (J. Zak, pers. comm.).

Aerial sprays are gaining acceptance because of their low per-hectare cost if applied on a large block. Many backlog sites in the northern Interior contain residual aspen or other deciduous trees which must be felled before aerial spraying, to ensure safe and homogeneous application (F. Gunderson, pers. comm.).

Backpack sprays are more costly than aerial applications, but are less controversial and more likely to be approved (F. Gunderson, pers. comm.). Furthermore, because drift-buffer zones are narrower, there is greater flexibility in the range of sites treated. Backpack spraying is ineffective or inefficient in brush more than about 2 m high. As well, there is a greater operator risk associated with backpack spraying than with aerial application.[8] Protective equipment worn by the operators, required by the B.C. Workers Compensation Board, restricts movement and limits effectiveness in heavy brush.

Rehabilitation options following herbicide use

After herbicide application, a number of options are available. Raw-planting of large stock pine or spruce can be carried out directly. If hexazinone was used, however, a 1-year buffer period is recommended. The success of this operation depends on the condition of the ground surface. If a duff layer remains intact, or if a litter layer has built up, seedling performance may be poor, even if stock quality and vigor are high.

On the other hand, a secondary mechanical treatment can be implemented such as disc trenching or mounding. If mechanical treatment follows the application of glyphosate before the herbicide has time to translocate to the roots, resprouting may occur (J. Perry, pers. comm.). Consequently, an appropriate time delay should be established on a site-specific basis.

4.5.2 Brown and burn

This option has been explored in a problem analysis by Vihnanek and Feller (1985), and is generally perceived as being a potentially effective way of achieving site rehabilitation by non-mechanical means. It is seen as a realistic option on sites in which mechanical site preparation is not feasible because of slope restrictions or sensitivity to heavy traffic. However, fireguards built by heavy equipment will still be necessary. It is also an option where knocked down backlog vegetation would not carry a broadcast burn. Its advantages are most clearly seen in herbaceous and shrubby complexes where windrowing is not an option.

An important limitation to the brown and burn method is that opportunities for burning in the wetter portions of the SBS become very limited after late summer. Thus, browning would have to take place in early summer, with burning no more than 2 months later.

The success of a brown and burn operation also depends on the presence of fuel to sustain the fire (B. Hawkes, pers. comm.). On failed plantations, browned vegetation will complement existing logging slash as fuel. The original logging method and site preparation treatment is therefore important. Many logged sites were not site-prepared, and were either planted as is or left for natural regeneration. Logging slash was left on the ground and is available for burning. Unfortunately the fine fuel component, which helps to carry and spread the burn, will have decomposed. In this case, browning of existing brush is required.

Older blocks that have previously been broadcast burned contain insufficient coarse fuel to sustain a rehabilitating burn. Similarly, if the failed plantations have been windrowed or piled, then fuel loads may not be sufficient for a brown and burn treatment.

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[8] Bancroft, 1987.

4.5.3 V-plows

V-plows have been used in the rehabilitation of recently logged backlog sites to clear brush and, at the same time, prepare planting spots. In the Prince George Forest Region, backlog rehabilitation plans are de-emphasizing V-plow treatments (M. Bruhm, pers. comm.) because of perceived site degradation, inconsistent creation of plantable microsites, and unsatisfactory seedling performance. (For discussion of microsite creation by V-plow, see Section 5.3.2.2.)

Suitability

V-plowing is perceived to be a realistic option in treating certain backlog sites dominated by herb and shrub complexes (B. Walker, pers. comm.). For example, V-plows have been used to clear trails and create planting spots on alder sites, provided the brush height is less than 4 or 5 m.

Generally, V-plowing is a questionable practice on fine textured soils (see Section 5.3.2.2). However, if a thick Ah horizon is present the treatment may produce satisfactory results. Such conditions are frequently associated with alder sites.

The treatment is considered appropriately drastic to set back vigorous competing vegetation, at least in the scarified trails. At the same time, planting spots can be found without further modification. Its main advantage is that it is far less costly than multiple treatments, and thus the rehabilitation budget can be stretched to cover more hectares. It also creates planter access. Treatments are cost-effective on accessible backlog sites, at least in the short-run. An attempt should be made to orient V-plow trails north-south, so that both sides receive insolation. On east-west trails, seedlings planted on the south (north-facing) side may be doomed to poor growth and low survival (Case Study 15, Appendix 1).

Disadvantages

The effective use of plows is largely limited to current NSR blocks, and as increasing emphasis is being placed on backlog sites which carry more successionally advanced vegetation, the use of V-plows appears to be decreasing. At the present time, the use of plows as a rehabilitation tool has been too recent for adequate assessment. Use of this implement in more advanced brush, however, has had mixed results (Case Studies 6 and 15, Appendix 1), at least partly because of shading and overtopping from shrubs and trees established between the trails. Other problems include hardwoods falling back into the trail, and the unplowed area serving as a refuge for rodents which clip newly planted seedlings (J. Perry, pers. comm.).

4.6 Old Logged Openings (Deciduous/Conifer)

Old Intermediate Utilization (I.U.) logged areas receive high priority in rehabilitation programs if they are near mills, accessible and treatable (M. Bruhm, pers. comm.).

If the sites contain sufficient merchantable timber (e.g., more than 140-150 m^3/ha, although this varies from district to district), then a timber sale can be negotiated with a local contractor or company, possibly with some subsidy in the form of minimal stumpage rates, to make the sale more palatable (F. Newhouse, pers. comm.). In this case, logging in the leave-strips can accompany the brush-clearing activities in the logged strips.

If the volume of residual timber is too small, or if it is diseased or otherwise of poor quality, the remaining rehabilitative option is to clear the site and plant. Knockdown has been accomplished by blades or by cables. For example, in the Lakes Forest District, knockdown of diameter-logged I.U. stands has been carried out using a cable behind two D-8 crawlers. Subalpine fir and cottonwood residuals with diameters up to about 35 cm have been knocked down in this fashion (K. Van Tine, pers. comm.). Operators can use slope to their advantage in cabling down large trees.

When these operations are completed, the entire I.U. block can be treated as a whole. Potential treatments include broadcast burning, pile and burn, brown and burn, and, of course, the full spectrum of secondary treatments if required.

The feasibility of a broadcast burn is very much dependent on the quality and distribution of fuel. Harvesting of merchantable timber may eliminate the potential for a broadcast burn, if insufficient fuel is left on the site. If a broadcast burn is felt to be the best treatment, falling but not harvesting the residuals may be the better option. As in other regions, residuals can be felled so as to maintain an even distribution of fuel.

In I.U. logging, diameter or selection logging is also included, leaving, smaller and/or less desirable trees. Clearance options are essentially the same as in strip-logged I.U. stands, except that residual falling may leave a more continuous slash, thus widening burning opportunities.

5 MICROSITE PREPARATION

5.1 Introduction

Once brush clearance has been accomplished as a first phase of rehabilitation, preparation of planting microsites is frequently necessary. However, rehabilitation on some sites may not require separate operations for brush clearance and microsite preparation. It may be found that brush clearance alone produces sufficient planting spots or affords a suitable seedbed. Similarly, certain site preparation treatments may provide sufficient freedom from competing vegetation, so that an initial brush clearance operation is not necessary. In most backlog situations, in which a substantial degree of brush competition is present, microsite preparation will be a necessary prerequisite for planting.

In north central British Columbia, options for site preparation are potentially wide, encompassing prescribed burning, a range of mechanical treatments, and various chemical and combination treatments. The biological objectives of site preparation vary considerably across the area, according to the gradients discussed in Chapter 2. Therefore, treatments deemed effective in one subzone are not necessarily effective in an adjacent one. Furthermore, the range of treatment options is constantly changing. New machines are being developed, others are being discontinued. Recent developments may be judged on superficial merits, such as the initial appearance of a treated block. The real test, namely establishment of a well-stocked, freely growing stand, may not yet have been properly assessed. On the other hand, promising new developments may be deferred because of over-caution on the part of conservative managers. New treatments may not initially receive optimum application; in some cases, several years may be required before their real value can be recognized. A bad first impression can be lasting.

In this section, the advantages and disadvantages of various site preparation techniques are reviewed, and related to site characteristics. Methods are classified according to their biological objectives, following the format in the Silviculture Manual, Chapter 5 (B.C. MOFL 1985b).

Figures 14 and 15 show historical site preparation methods by regions. Figure 14 compares the two major zones (SBS and BWBS) in the study area; Figure 15 compares the site preparation history of the Prince George, Prince Rupert, and Cariboo forest regions in the SBS zone. Data were obtained from history records as of November, 1986.

5.2 Prescribed Fire

5.2.1 General considerations

Prescribed burning has not been extensively used in rehabilitation, mainly because of the less favorable fuel characteristics of backlog, as compared to current sites. Nevertheless, because prescribed burning has such important implications for subsequent backlog conditions, its characteristics should be understood.

Burning is used as a site preparation technique throughout the SBS zone and sporadically in the BWBS zone. Most broadcast burning is carried out in preparation for artificial regeneration of spruce and, to a lesser extent, pine. It is the predominant form of site preparation for planting in north central British Columbia.

Seedling performance

Seedling performance following outplanting in suitably burned sites is widely believed to be superior to that on mechanically treated sites, although data are lacking (B. Bye, pers. comm.). In reviewng plantation performance in the Prince George Forest Region, Draper (1983) found that the 14 "best" plantations were all burned. This in part reflects the fact that fully 88% of the 173 plantations he sampled were burned.

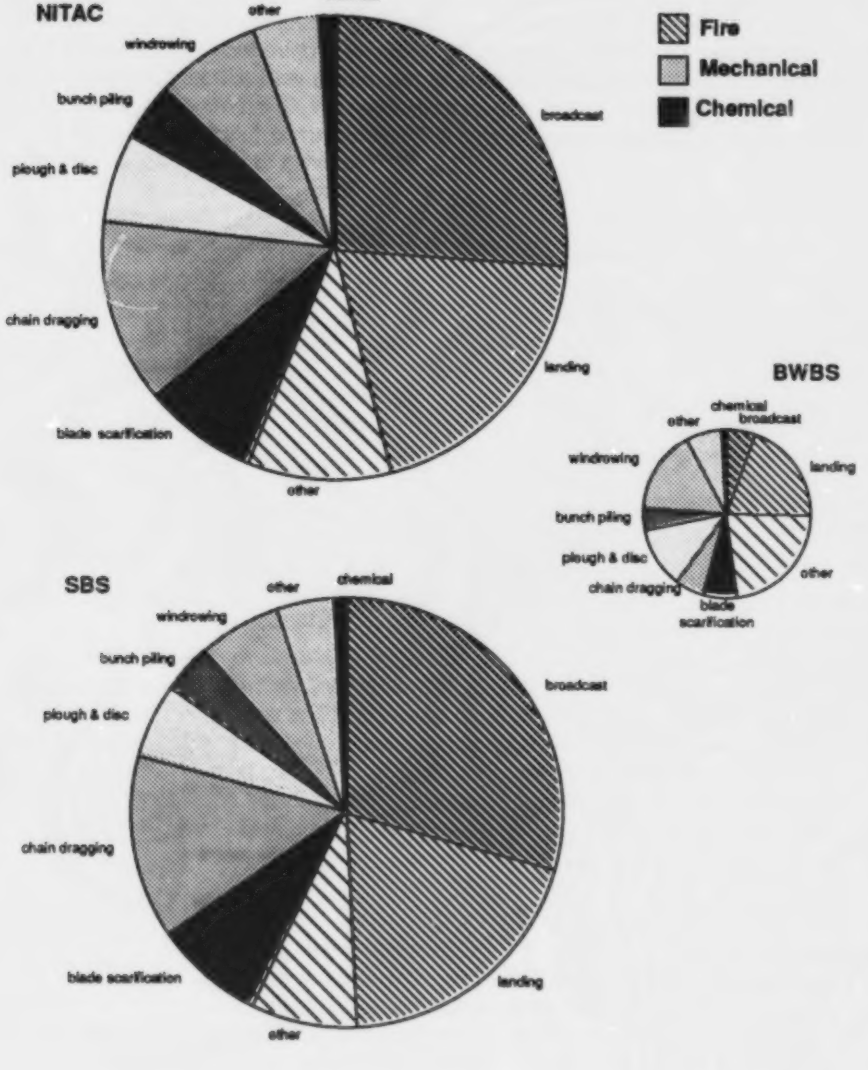

FIGURE 14. Comparison of the percentage use of various methods of site preparation in the BWBS and SBS zones of the northern Interior. The area of the circle corresponds to the total area on which site preparation had been conducted up to and including 1986.

The main reason for inconclusive evidence supporting this observation is the variability in prescribed fire impacts and the lack of statistically valid comparisons (R. McMinn, pers. comm.). Attempts to quantify the effectiveness of burning (or any other site preparation) by assessment of existing plantations are complicated by variability in treatment application as well as in numerous other factors (e.g., weather

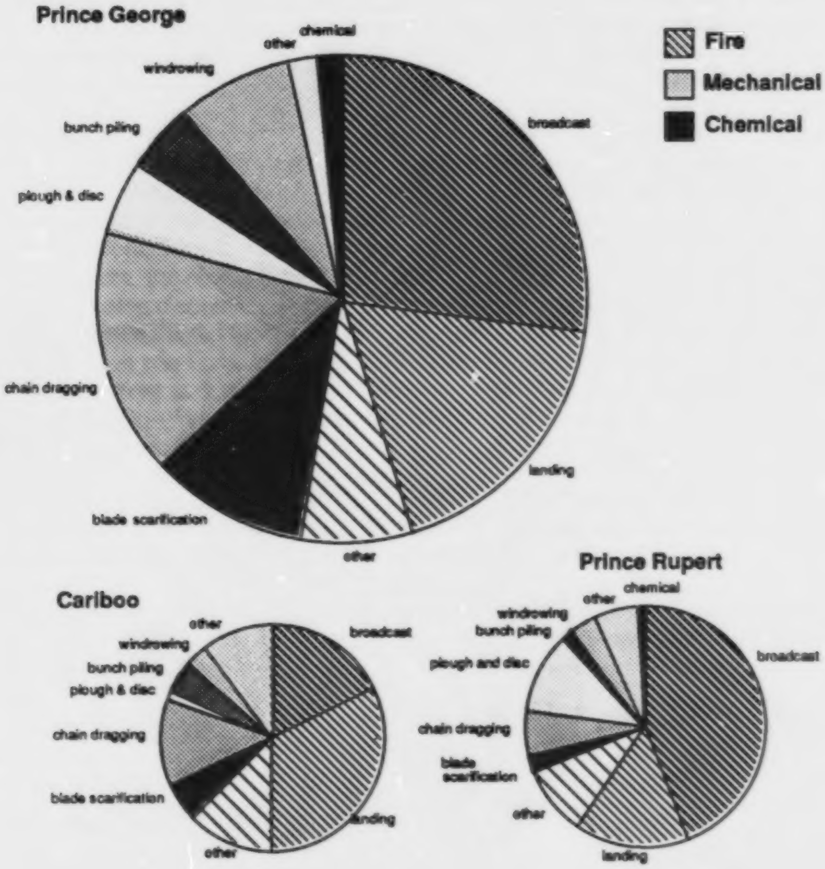

FIGURE 15. Comparison of the percentage use of various methods of site preparation in the SBS zone within northern Interior forest regions. The area of the circle corresponds to the total area on which site preparation was conducted.

conditions during and following planting, and phenology of vegetation). A standard methodology for assessment of prescribed fire impacts is, however, now available (Trowbridge *et al.* 1986) and should improve assessment in the future.

Overall, the treatment is considered to be, on suitable sites, the cheapest and most effective option (B.C. MOFL 1985) especially since it also may provide good slash reduction, planter access, disease control and a certain degree of vegetation control.

Drawbacks

Prescribed burning, like all other site preparation treatments, has drawbacks. Its major limitation is control. Although the cost of broadcast burning compares favorably with that of other treatments, that cost carries a risk of escalating enormously if anything goes wrong. Many managers, understandably, are not prepared to undertake that risk. Fear of escapes has led to a paucity of experience with prescribed burns in some areas, such as the BWBS (B. Wesleyson, pers. comm.). However, the risk associated with burning can be minimized by careful planning and the use of appropriate techniques. Small areas, especially, may be difficult and costly to burn.

Uncertainty

Successful completion of a prescribed burn cannot be guaranteed. The satisfactory execution of a broadcast burn is highly dependent on a number of climatic and site-specific factors which are beyond the control of forest managers. Burning windows may be too narrow to treat all the blocks which carry burning prescriptions (B. Bye, pers. comm.). Ideal conditions are required to perform a successful burn. If the duff moisture level, for example, is too high, the burn may ignite and spread, but intensity will be low and objectives may not be satisfactorily met. If, on the other hand the moisture level in the duff is too low, an excessively high impact burn will take place, which may lead to site degradation and thus nutrient and erosion problems.

Potential site degradation

Site degradation can result from prescribed burning. Fear of long-term productivity loss precludes the use of prescribed fire on sensitive sites. For example, burning should be avoided on xeric ecosystems where much of the nutrient capital is concentrated in the duff layer (Pojar *et al.* 1984). Guides for identifying sensitive ecosystems are available in British Columbia (e.g., Klinka *et al.* 1984): these warn against burning sites vulnerable to erosion when mineral soil is exposed (steep slopes, erodible soil), or where loss of nutrient pool or water-holding capacity will detrimentally affect stand development. In general, broadcast burning is suitable for mesic and wetter sites in most subzones, where block design, slash loads and duff layers permit. However, within each subzone there may be disagreement about such matters as the threshold values of duff thickness at which broadcast burning may be allowed (B. Hawkes, pers. comm.).

Nutrient depletion

Although nutrient depletion takes place following slashburning, evidence of long-term effects on tree growth is contradictory (Feller 1982). In the northern Interior of British Columbia, Ballard (1984) found that the frequency and severity of a number of nutrient deficiencies were greater in young spruce trees growing in plantations that were either mechanically treated or slashburned, than in plantations that were untreated. Growth, however, was better in the former plantations, suggesting that the improved conditions afforded by these treatments more than compensated for the loss of nutrients.

Insects and disease

Black army cutworm (*Actebia fennica*) is a multiple host pest which attacks young plantations throughout British Columbia. The heaviest concentrations appear to occur on openings burned during the previous 1 or 2 years (Ross and Ilnytski 1977). For example, 10 of 31 plantations in recently burned openings in the Morice, Lakes and Bulkley TSA's were affected in 1985 (Wood and Van Sickle 1986). As a consequence, planting programs may be delayed, or site preparation methods other than prescribed fire may be employed.

Also associated with prescribed fire is the rhizina root rot (*Rhizina undulata*), which may affect seedling survival during the first growing season. Incidence of this fungus is, however, rather low in the SBS and BWBS zones (e.g.,Wood 1986).

Brush control

One of the major advantages of burning as a site preparation is brush control. A high impact fire will usually set back competing vegetation for several years, creating a competition-free window in which spruce or pine seedlings can establish and attain a free-growing status. However, the degree to which brush control is effected is highly variable, depending on intensity of burn, site conditions and brush species. Low impact burns which do not destroy the majority of weed rhizomes may in fact exacerbate the brush problem on a site (see, for example, Case Study 9, Appendix 1). In general, fire has its greatest effect on underground storage organs in the spring when carbohydrate reserves are at their lowest and thus most vulnerable (Cleary *et al.* 1978). Unfortunately, in north central British Columbia, early season burns seldom achieve an adequately high impact on moist sites (B. Hawkes, pers. comm.).

Aspen

A number of brush species are ecologically adapted to regenerate after fire. Aspen (*Populus tremuloides*), for example, is known to sprout vigorously following fire (Haeussler and Coates 1986). Burning can therefore aggravate aspen competition where it forms part of the pre-logging stand.

Fireweed

Fireweed rhizomes will be killed by high impact burns, but due to its prolific capacity for seeding, it can colonize burned blocks quickly and may establish a dense cover within as little as 1 year. Except at the end of the growing season, fireweed has a high moisture content and, hence, low flammability (Sylvester and Wein 1981, cited in Haeussler and Coates 1986).

Low impact burns can stimulate fireweed growth. On one mesic site in the Morice District (SBSe1), a broadcast burn had escaped into an adjacent area in which the slash was not heavy enough to carry a very intense fire. Within 1 year, fireweed was over 1 m tall, and smothering spruce seedlings. It seems likely that the burn was not enough to kill the fireweed rhizomes, and vigorous sprouting took place the following year.

Reedgrass

Reedgrasses (*Calamagrostis* spp.) can also constitute a competitive threat following fire. These plants are tolerant of burning, as well as capable of prolific seeding-in following fire (Haeussler and Coates 1986).

5.2.2 BWBS

Historically, prescribed fire has not been an important site preparation option in this zone. A total of 4606 ha (or 5.67% of the total open area to 1986) has been treated by broadcast burning in preparation for planting. On a percentage basis, burning is prescribed less often here than anywhere else in the study area. Conversely, wildfires account for fully 16% of the total area disturbed, much higher than in any other region (Fig. 14). The higher incidence and/or extent of wildfire can be attributed to the more continental climate experienced in this area, characterized by warm, relatively dry summers and consistent winds. Natural fire is an integral part of the dynamics of boreal forest ecosystems (e.g., Annas 1983), perhaps even more so than forest ecosystems west of the Rockies.

Managers have been reluctant to use prescribed fire in the BWBS because of difficulties with control (e.g., H. Krawczyk, pers. comm.). However, several interviewees expressed a desire to increase the use of prescribed burning as a site preparation tool (B. Wesleyson, pers. comm.).

If aspen or reedgrass form part of the pre-logging ecosystem, a low impact fire can stimulate one or both of these species to the extent that they will pose a hazard to newly planted seedlings (L. Herring, pers. comm.)

Burning was also seen as an important alternative to mechanical treatment on steep, inoperable slopes, and on sites with heavy slash or deep duff (W. Thorp, pers. comm.). These sites need to be identified before logging is carried out, so that appropriate planning is undertaken (G. Cissel, pers. comm.).

5.2.3 SBS (Group 1: SBSj1, j2, f, and n; "wet" units)

Broadcast burning is both the most popular and most widely practiced treatment for site preparation in this area. For example, in the Prince George East Forest District, about three-quarters of all treated openings were broadcast burned in 1985 - although not all of these were intentional (B. Bye, pers. comm.). Most silviculturists interviewed indicated that they would like to see more prescribed burning. Furthermore, most felt that survival and/or initial growth were superior following burning compared to mechanical treatment. Burning was identified as a strongly preferred treatment on steep slopes or moist, fine-textured soils where mechanical treatment is inefficient or liable to lead to site degradation.

Broadcast burning, according to the History Record System, has evolved from the early 1970's, when the primary objective was hazard reduction, to the present time when the primary objective is planting spot preparation. Hazard reduction and planter access are still, of course, important benefits. Target impacts need to be high enough to reduce duff depth sufficiently to provide planting spots, as well as to set back competing vegetation. Increasing effort is now being placed on improving local skill at identifying, then achieving, the desired impact on any particular site (B. Hawkes, pers. comm.).

Obtaining a high enough impact on wetter sites and a low enough impact on drier sites is a problem (P. Sears, pers. comm.). Planning and executing a burning program can be very difficult if windows are narrow (F. Gunderson, pers. comm.). Duff moisture levels are seldom low enough in subhygric and hygric ecosystems to allow adequate heat penetration below the surface to consume duff or to kill the roots of competing vegetation. On these sites, ignition is not so much of a problem as is obtaining the desired impact (N. Crist, pers. comm.). Inadequate duff consumption may result in a persistent brush problem. It has also been noted that on hygric sites, fuel loads may be thin and scattered, further reducing the opportunities for burning (B. Richards, pers. comm.). To achieve higher impacts on wetter sites, burning in July and August may be necessary (D. Presslee, pers. comm.). A number of licensees have recently carried out summer burns with good results and no major escapes (N. Crist, pers. comm.).

The Prescribed Fire Predictor (Muraro 1975) is widely used and generally considered satisfactory. On spruce-balsam slash, the type commonly encountered in this area, it tends to under-predict reduction in slash (<22 cm), but predicts duff consumption to within 20% (Lawson and Taylor 1986).

5.2.4 SBS (Groups 2 - 5)

Questionnaire respondents generally indicated that in this area, prescribed burning was the "most successful" and "should be used more frequently." One respondent, specifying the SBSe2 variant, stated that 90% of seedlings planted on burned sites are freely growing after 7 years, whereas the correponding figure for windrowed sites was only 40-50%.

Dependence on the use of prescribed fire varies considerably over this area, depending on climatic and ecological conditions (i.e., burning windows), personal preference, and experience. Burning windows are generally wider here than in the wet biogeoclimatic units of Group 2. Some interviewees included broadcast burning as a treatment falling out of favor because of problems with control (B. Walker, pers. comm.). In general, treatment costs are lower than alternative means of site preparation, but some respondents indicated that these did not take into account the risk of escape. Many respondents stated the need for "high impact burns" on wetter sites that usually required summer ignition. However, such burns are potentially risky. In 1986, for example, a number of expensive escapes occurred in the SBSe2 near Carp Lake, resulting from mid-summer burning (B. Baker, pers. comm.).

Burning of mesic and drier sites can possibly lead to nutrient deficiency problems later (see Case Studies 23 and 24, Appendix 1). In a study 90 km north of Houston (SBSe1), Taylor and Feller (1986) examined nutrient losses on mesic (01) and subhygric/hygric (08-09) sites. The mesic site suffered substantial losses of nutrients under low and moderate impact classes, ranging from 56% of total sulphur to 33% of total magnesium in the slash and forest floor. Losses on the subhygric/hygric site were much less. In the SBSe2, spruce planted on sites that had been severely burned are showing severe magnesium deficiency, despite good initial survival and growth (P. Sears, pers. comm.).

In the southwestern portions of the Vanderhoof District (SBSe1 and i), a secondary mechanical treatment, such as mounding or disc trenching, has been used as a follow-up to burning (either prescribed or accidental). The primary objective of the prescribed burn was to reduce logging slash, and not to consume duff layers. Thus, burning windows were widened, since burning could go ahead even at high moisture levels. Although this treatment was applied to a recently logged site, it may have application to backlog sites.

5.3 Scalping

Scalping is the removal of the duff and humus layers, and the exposure of underlying mineral soil. The purpose of this practice is, first, to warm up mineral soils, thereby allowing root egress and minimizing planting shock; and, second, to eliminate competing vegetation. In the northern Interior, scalping treatments include blade scarification, V-plowing, brush blading (depending on the manner of operation), patch scarification and disc trenching.

5.3.1 Effects on seedling performance

Scalping, or screefing, has been shown to significantly improve the performance of planted spruce (Lees 1972; Stiell 1976). In one trial (McMinn 1985d), spruce seedlings planted on scalped sites were more than 60% taller than seedlings on untreated sites. However, performance of planted stock on scalped may be inferior to that on mixed or inverted microsites (McMinn 1985a).

The effectiveness of scalping in preparing a site for growing spruce or pine is very much dependent on the nature of the underlying mineral soil (B.C. MOF 1985). Where soils are medium to coarse textured, scalping exposes a rooting medium with favorable physical characteristics, allowing unimpeded root extension (R. McMinn, pers. comm.). This, in combination with an improved thermal regime, may sufficiently compensate for lack of nutrients. In time, roots can extend into adjacent undisturbed areas and there tap nutrients for continued growth.

Scalping would be an inappropriate treatment in soil with unfavorable physical characteristics, for example, Luvisolic soils developed in fine-textured glacio-lacustrine parent materials. Planting in scalped soil under these conditions may lead to poor root extension and possible frost-heaving.

On the other hand, scalping coarse-textured soils (such as sands) may result in such poor nutrient and moisture retention that the improved thermal regime cannot compensate (Ezell and Arbour 1985; McMinn 1985a).

Scalping can effectively remove the roots of competing vegetation, thereby providing a competition-free window of up to several years for the establishing seedling. It is most commonly used in the wetter biogeoclimatic units of the SBS (i.e., the j1, j2, o, f, and moister ecosystems of the e2), where vegetative competition and low soil temperatures are the primary obstacles to seedling establishment.

5.3.2 Methods

5.3.2.1 Blade scarification

Blade scarification is normally carried out using the angling blade of a bulldozer. It therefore has the advantage of freely available equipment and operators. The preparation of biologically suitable microsites by blade scarification has been extremely variable, due to the wide range of operator skill and objectives, site conditions, and equipment used. The use of blades may be inefficient because of the difficulty in dispersing slash. On sites in which slash loading is heavy, blade scarification may involve frequent reversals to unload debris.

5.3.2.2 V-plows

V-plows are used on sites with moderate to heavy slash, preferably on slopes less than 30%. They have been used as an alternative site preparation treatment where burning is either not feasible or was attempted with poor results.

The V-plows produce an effect similar to blade scarification, but because of the plow sole and the "V" shape, more mixing on the berms theoretically takes place. Plowing sometimes results in too much movement of soil, but too little mixing of organic material with mineral soil (S. Knowles, pers. comm.). The degree of soil disturbance in the trail is highly variable, depending on the skill and objectives of the operator. The difficulty in matching scalping depth to site conditions is a widespread limitation. Operation on moist sites leads to considerable rutting, and seedlings planted on the trail are frequently subject to flooding (Case Study 6, Appendix 1; Fig. 16).

Disadvantages include the great weight of the implement (which can vary between 2000 and 3000 kg, or up to 3600 kg for the C&H plow). As this weight is forward-mounted on the crawler tractor, traction is sometimes adversely affected, especially on wetter sites (R. McMinn, pers. comm.). The size of the implement makes it unwieldy. The length is particularly disadvantageous, especially on uneven terrain, where gouging is virtually impossible to avoid (R. McMinn, pers. comm.). The design of the plow is variable, having been modified and adapted by several users in the northern Interior.

In general, efficiency is greatest where machine operation is not hindered by broken terrain, closely spaced stumps, and full-tree slash (B. Walker, pers. comm.). Operation is seen to be more difficult on winter-logged sites because of greater stump height. Trails are normally created along the contour on gentle slopes (up to 15-20%, depending on operator) and directly up- and downslope on steeper sites. Consequently, operation on slopes above 25% is not recommended (Coates and Haeussler 1984) because of excessive erosion and site degradation. Furthermore, production efficiency is drastically reduced because operation is only possible on favorable grade, meaning that the machine plows downslope, and "walks" back.

FIGURE 16. V-plow rehabilitation on a subhygric to hygric (05) ecosystem (spruce-horsetail) in the Mackenzie Forest District (SBSj2). This spruce seedling, planted in the trail, was killed by flooding. (Case Study 6, Appendix 1).

Microsite selection

Planting in the trail itself was common until fairly recently: those seedlings are now frequently dead or in poor condition (see Case Studies 2 and 6, Appendix 1). However, R. McMinn (pers. comm.) has observed a V-plowed site on silty loam with a thick Ah horizon, in which spruce (planted in the middle of the trail) were stunted and slow-growing at age 5, but had recovered by age 10.

In sites where scalping treatments have caused rutting or compaction, planting microsites are restricted to the suitable parts of the berm of mixed mineral and organic soil on either edge of the bladed trail. Planting on top of the berm may not be desirable, because of looseness of the soil and competition from vegetation (R. McMinn, pers. comm.).

Selection of planting microsites appears to be critical (Case Study 7, Appendix 1). Closer supervision and instruction are becoming the norm (B. Williams, pers. comm.), with planting restricted to carefully chosen spots on berms.

Brush control

Brush control by V-plows received a variable rating, depending on different experiences on different sites. Most respondents perceived that V-plowing affords better and longer lasting brush control than other treatments (e.g., windrowing). This is substantiated in one case by Herring (1981) who found that brush was somewhat less following C & H-plowing than following treatment with sharkfin barrels.

There appears to be a potential for trails to seed-in to Sitka alder (*A. viridus*), willow, birch, and cottonwood over time, even where compacted and degraded, and that these may later interfere with the achievement of free-growing status. Exposing substantial areas of mineral soil will probably lead to later brushing-in by these species if a seed source is present (R. McMinn, pers. comm.).

Long-term effects

Little documentation on the long-term effect of this degradation on seedling growth is available. In the southern United States, Ezell and Arbour (1985) found that differences in organic matter content between V-plowed and untreated microsites persisted after 10 years.

Summary

In summary the disadvantages of using plows for scalping are:

1. exposure of mineral soils to frost-heaving (in susceptible soils);
2. risk of flooding or saturation in depressions;
3. difficulty in controlling scalping depth;
4. inconsistent microsite creation;
5. nutrient depletion; and
6. risk of site degradation.

5.3.2.3 Ripper plow

The ripper plow is used almost exclusively on frozen soil on sites that are inaccessible in summer. Inaccessibility can be due to lack of summer access or poor on-site tolerance of heavy traffic. Details are given in Coates and Haeussler (1984). The implement is used in both SBS and BWBS zones, but in 1986 was more extensively used in the latter.

The plow consists of a ripper tooth and cutting edge, and moldboards that disperse the clods on either side. It was designed to create a trench approximately 50 cm deep with raised berms on either side (Coates and Haeussler 1984).

In practice, the size and shape of the trails were observed to be highly variable because of surface roughness and slash. The tooth shatters the frozen soil into hard clods of various sizes, which then settle during the following summer into heaps and mounds. Depending on the design of the moldboard plow attached to the tooth, some of these clods may roll back into the trench (B. Wesleyson, pers. comm.).

The degree and rate of settling depends on the moisture content of the clods. If nearly saturated, a high degree of deformation to the berms and trench may take place following snowmelt. This appears to be a major limitation on subhygric and hygric sites in which extensive settling has eliminated much of the initially raised microsites. Alternatively, clods created in fine-textured soils may require a prolonged period in which to break down.

On moist sites, the creation of trails directly up- and downslope facilitates drainage, an important secondary benefit. However, trails on moderate slopes (> 10%) in areas of silty soils may experience severe erosion and loss of planting sites. In such cases, intermittent lifting of the plow is recommended (Coates and Haeussler 1984). Normally, one plow attachment is used, thereby creating one trail per pass of the prime mover. Width of the trail is variable and depends on the implement that has been adapted by each user. Peace Wood Products uses a twin plow, thus creating two trails per pass (C. Kowalski, pers. comm.).

Coates and Haeussler (1984) report that the ripper plow was rated good to excellent for reducing grass and brush competition. However, trails examined in the course of this project were frequently so narrow that only a minimal brush-free swath was created. Grass and brush on undisturbed ground on either side of the trails had commonly overcome planted seedlings.

Heavy slash loads can interfere with operation of the ripper plow. It has been suggested that the prime mover be equipped with a brush blade to disperse slash on first-pass treatments (C. Kowalski, pers. comm.). The ripper plow is frequently used as a second-pass site treatment following windrowing.

Questionnaire respondents rated the ripper plow as both the best and worst treatment, and this disparity is probably explained by the range in plow designs and types of sites treated. It would appear to be best suited for medium-textured soils on gentle slopes, where drainage would be beneficial. A trade-off needs to found between size and shape of moldboard (for adequate creation of planting spots) and power requirements of the implement. For proper vegetation control, bigger is better, but available prime movers can accomplish only so much, especially in frozen ground. The sites on which ripper plows are usually prescribed have few alternatives in the way of mechanical treatment.

5.3.2.4 Brush blades (windrowing and piling)

The use of brush blades to clear large debris into rows can be considered a form of scalping. Spot piling ("rough-bunching") is a closely allied treatment. The choice of spot piling or windrowing is dictated by site characteristics and personal preference. For example, spot piles can be packed more tightly so as to allow a more effective burn (G. Cissel, pers. comm.).

This treatment is one of the most commonly practiced in the study area (about 10% of disturbed area was windrowed and piled) according to history records. Formerly, straight blades were used to accomplish this operation, but because of excessive loss of topsoil, they have been largely replaced by brush blades.

The brush blade is intended to "float" over the ground surface, to move heavy debris while simultaneously creating scalped planting spots as the tines move through the soil (Coates and Haeussler 1984).

Microsite creation

Numerous questionnaire respondents indicated that windrowing or piling by itself does little to prepare planting spots, and that a follow-up treatment is required. The degree of mineral soil exposed is highly variable, depending on the skill and objective of the operator, and on whether the operation is carried out on frozen or unfrozen soil.

Severe treatments tend to remove too much surface organic matter, reducing site quality (see Case Study 11, Appendix 1). Overly light treatments produce inadequate plantable spots because of intact duff layers. For example, in one mesic site on glacio-lacustrine soils in the Mackenzie District, windrowing by a brush blade left over 10 cm of duff intact and exposed virtually no mineral soil, thus necessitating a second-pass treatment.

Brush control

Although the tines of the brush blade can break up root systems of many brush species (P. Sears, pers. comm.), sprouting species are not necessarily inhibited. Many sites subjected to windrowing without further treatment were observed to have brush problems after several years (see Case Study 7, Appendix 1). The degree of brush control depends on the severity of the treatment. Too little disturbance leaves the site vulnerable to sprouting vegetation, such as thimbleberry, red raspberry, and aspen (Case Study 7, Appendix 1). On the other hand, too much mineral soil exposure may result in invasion by seeding-in species (P. Sears, pers. comm.). Intensive treatment on moist sites may cause an unacceptable degree of rutting and soil degradation.

Where burning of the piles or windrows is required or intended, one growing season is commonly lost, since that time is needed for the slash to dry out sufficiently to allow an effective burn. This can be a problem if the site is winter windrowed or piled, because little ground disturbance results and, consequently, little vegetation control is achieved. The loss of a growing season is therefore a disadvantage, as every lost season increases the risk of regeneration failure.

Windrowing on brush-prone sites will probably require some follow-up treatment, either herbicide application or mechanical preparation (D. Presslee, pers. comm.). Although relatively expensive, this is increasingly being perceived as a good alternative (B. Williams, pers. comm.). Many second-pass treatments are more effective on windrowed sites (C. von Hahn, pers. comm.). Sites that are not inherently prone to brushing in appear not to need follow-up treatments if they are planted reasonably promptly (Case Study 8, Appendix 1).

Types of brush blades

A number of alternatives exist for the conventional brush blade, with its fixed tines. The Eden brush rake - described in Coates and Haeussler (1984) - and the Raumfix both have tines which retract when encountering stumps or low obstructions. The objective is to reduce ground disturbance, but it also alleviates the frequent shocks imposed on machine and operator, and reduces the amount of time needed to negotiate around stumps. Both implements are designed for a skidder (although the Eden rake is also designed for a crawler). Consequently, these new implements may be more productive and/or cheaper than the conventional brush blade on sites where skidders can be used.

Relatively little experience has been accumulated with the Eden piling rake, although preliminary observations suggest that it achieves a clean result on appropriate sites (C. von Hahn, pers. comm.). The Raumfix was introduced on the British Columbia scene in 1986, but is not yet used on an operational scale. As with most site preparation equipment, brush rakes are continually being updated and improved.

The FMC with 4- or 6-way blade has also been used in the SBS for windrowing or spot piling. Its use is largely confined to steep sites or those with poor tolerance of heavy traffic. The FMC can operate along the contour on slopes up to 45% (Coates and Haeussler 1984). Using the dip and dive technique, even steeper slopes can be treated. The design of the blade allows the operator to keep it close to the ground on uneven terrain.

Several interviewees regarded the FMC as unreliable, slow and expensive to operate and maintain. However, it may be the only option on difficult sites such as steep, north-facing slopes which cannot be burned.

FMC's are also used for yarding timber off difficult sites. Increasing experience with the machine, along with continuing modification and improvement, may lead to its greater use in microsite preparation.

5.3.2.5 Disc trenchers

Disc trenchers are increasingly used for microsite preparation in the northern Interior. The three basic types are:

1. passive;
2. hydraulic down-pressure only; and
3. hydraulic down-pressure and powered.

Passive discs are propelled by ground friction as they are dragged behind the prime mover. This type includes the CFE (M&M) disc trencher and the TTS 35 (Coates and Haeussler 1984). The second type has discs also moved by ground friction, but they are subject to variable down-pressure, which maintains contact between the discs and the ground. Examples of this type are the Donaren 180 and the TTS Delta (which can be powered or unpowered). Powered trenchers used in Canada include the Donaren 180D and 280, the TTS HS, and the Wadell.

In 1987, there were 18 trenchers in use in British Columbia (L. Bedford, pers. comm.), of which 6 were passive, 2 had hydraulic down-pressure only, and the remainder (10) were powered.

Microsite creation

In ideal conditions, trenchers create a more or less continuous furrow, with surface debris and duff scattered to one side. However, in moderate to heavy slash, the implement may ride up in places, thus missing spots. For example, in a comparative study carried out in Ontario, plantable spots created by a passive TTS disc trencher on a clean, full-tree logged site were more frequent and generally of higher quality than those created by the same machine on a tree-length logged site (Rodney Smith *et al.* 1985). Hedin (1985) has suggested that increased efforts to reduce slash loading on the site may pay off later, with reduced site preparation costs, using trenchers. Disc trenchers with variable down-pressure and those with powered discs will probably be more effective on a wider range of sites than passive trenchers (Hedin 1985). In the Vanderhoof Forest District, a powered TTS Delta with down-pressure has achieved good results on sites with "moderate to heavy" slash (C. von Hahn, pers. comm.). Furthermore, skidders with V-plows attached allow a greater range of slash conditions to be treated.

The trench can be beneficial in providing drainage on sloping sites which are imperfectly or poorly drained. A continuous trench also facilitates easier planting site selection, especially on fill-in planting operations (B. Walker, pers. comm.).

Downslope trenching may carry a risk of erosion (B.C. MOF 1985). Where this risk is high, the use of machines capable of intermittent trenching, for example the Donaren 280, may be advantageous.

Brush control

On brush-prone sites, disc trenchers may not achieve the necessary degree of vegetation control. For this reason, disc trenchers are used more frequently on current sites in the drier parts of the SBS rather than in the "wet" biogeoclimatic units (SBSj1, j2, j3, f, and n) and in the BWBS (according to questionnaire response). Disc trenchers are used throughout on rehabilitation projects as second-pass treatments.

On grassy sites, trenchers flip over the sod which then may flip back into the trench later (B. Wesleyson, pers. comm.). However, the general significance of this effect has yet to be determined.

5.3.2.6 Patch scarifiers

An alternative to the use of blades and plows for scalping is the use of patch scarifiers. These create discontinuous scalped patches by the use of tines attached to mattock wheels which follow the prime mover.

According to McMinn (1985a), seedlings planted in patches may overcome potential nutrient deficiencies because roots can soon reach the relatively nutrient-rich soil underlying adjacent undisturbed organic matter.

In the northern Interior, the Leno, the Bräcke, and, more recently, the HMF Sinkkilä Mounder are examples of patch scarifiers currently in use. Although the Sinkkilä can be used as either a patch scarifier or a mounder, it has been used almost exclusively as a mounder since its introduction to British Columbia in 1986 (L. Bedford, pers. comm.).

The intermittent nature of the disturbance may also minimize soil erosion, and this may be an important factor in silty or very fine sandy soils which are vulnerable to erosion. On the other hand, since the action of the tines is usually to create a small depression, especially where the duff layer is fairly thick, water may collect in the patches, producing waterlogged conditions. Futhermore, the small size of the screef may be inadequate in areas of strong vegetative competition.

Microsite creation

Planting at the bottom of the screefed depression contributes to seedling mortality on some sites (B. Baker, pers. comm.). Flooding in the spring, frost-heave, and unfavorable physical and thermal properties are some of the direct causes of death. However, planters may find a range of microsites in screefs created by the Bräcke. Frequently only the very lowest parts of the depression are flooded (L. Bedford, pers. comm.).

Nevertheless, planting in depressions may be suitable in drier parts of the SBS (for example the "d" subzone), where growing season moisture stress is a factor (Case Study 19, Appendix 1). The nature of the exposed subsoil is critical in determining success. For example, if the screef exposes a very firm subsoil, then root growth will probably be poor.

Seedlings planted in the depression have a height disadvantage compared to competing vegetation. For example, in comparing screefed (to mineral soil surface) microsites with mounds, Draper *et al.* (1985) found the former received 14% of daily background photosynthetically active radiation, whereas mounds received over 70%.

The Leno scarifier created screefed depressions about 10-20 cm deep, depending on the thickness of the duff layer (Case Studies 19 and 20, Appendix 1). The screefs were about 30-40 cm wide. Screef length is hydraulically controlled and therefore adjustable. On sites prone to brushing-in, screefs have been perceived to be too small to provide effective brush control (P. Sears, pers. comm.). The treatment is also not suited to sites with deep duff layers, obviously because mineral soil would not be exposed.

The Bräcke scarifier produced a similar effect. Patch size and density can be varied by using different chain-driven gears or by changing mattock wheels to alter the number of paired tines.

The effectiveness of the patch scarifiers was disputed. In some cases, spruce plugs planted in Leno patches suffered serious frost-heave damage (J. Casteel, pers. comm.). Planting in depressions may leave the seedlings vulnerable to spring flooding, low temperatures, and overtopping by surrounding vegetation, especially in cold, fine-textured soils. These problems are associated in part with planting site selection.

However, on appropriate sites, with light to moderate slash loads, moderate duff layers, and well-drained friable soils, the patch scarifiers may produce an acceptable number of plantable spots (F. Gunderson, pers. comm.). In the drier parts of the SBS (for example, the d subzone), planting in the depression may be beneficial if moisture stress is a problem (Case Study 19, Appendix 1). On subhygric sites, however, planting in depressions is likely to be unsuccessful (Case Study 20, Appendix 1).

Site constraints

A general perception amongst questionnaire respondents was that the Bräcke and Leno patch scarifiers are not suited to sites with moderate to heavy slash or deep duff layers. Most interviewees accepted the biological principles involved in patch scarification, but considered the machines too unreliable or simply incapable of coping with the slash and terrain encountered during conventional site preparation (D. Presslee, pers. comm.).

The weight of the Bräcke posed difficulties in wet ground and in negotiating sloping terrain. In the Mackenzie Forest District, excessive winching was reported when the unit was used with a Timberjack 450T rubber-tired skidder on slopes over 15%, or over 10% in heavy slash (Knowles 1981), although the use of a more powerful D7F crawler as the prime mover reduced this problem.

The Leno was considered, however, to be less maneuverable on difficult sites because it could not be cabled out and winched (F. Gunderson, pers. comm.). Coates and Haeussler (1984), on the other hand, state that the Leno is much more maneuverable than the Bräcke, mainly because of its lighter weight. The Leno can also be lifted clear of the ground by the prime mover. A V-plow or other dispersing implement may widen the range of appropriate sites for both the Leno and Bräcke scarifiers (B. Walker, pers. comm.).

Brush control

Neither the Leno nor the Bräcke patch scarifiers were perceived to be effective on brush-prone areas. However, a new development, the Bräcke Herbicider, may change that. This unit is essentially a patch scarifier to which herbicide spray equipment is added. Herbicide can be delivered onto the ground via side or rear nozzles, or can be broadcast from a mounted boom. Both soil-active and foliar herbicides can be used, depending on permit approval.

Manual and motor-manual screefing

Scalping or screefing can also be accomplished by planters who manually remove a certain minimum area of humus at each planting spot. (The B.C. MOF [1985] recommends a 30 by 30 cm screef or 900 cm^2.) This is an alternative in areas of relatively thin duff, or where fill-in planting is required. A screef this size will usually not be adequate in areas of heavy brush competition. An alternative to manual screefing is motor-manual screefing, usually performed by a specially designed implement mounted on a brush saw or chain saw.

5.3.3 BWBS

V-plows

V-plows have been used in the BWBS, but reports of their effectiveness have been conflicting. Questionnaire respondents considered the V-plow to be best suited to mesic sites with medium to heavy slash loads which cannot be burned. Severe scalping, especially on moist mesic to hygric sites, has been reported to lead to heavy mortality (B. Wesleyson, pers. comm.).

Case Study 15 (Appendix 1) represents a site in the BWBS zone which was subjected to V-plow treatment. Seedlings planted on the trail performed poorly, but those along the berms were satisfactory. Berms consisting of mixed organic and mineral material appear to have suitable physical characteristics for root elongation. Brush control on the trails was good (although willow was beginning to seed-in after 6 years), but vegetation between the trails was shading out seedlings, especially those on the southern berm.

Straight or road-building blades are now infrequently used in the BWBS, with the exception of the Fort Nelson area (S. Lindsay, pers. comm.).

Brush blades (windrowing and piling)

According to history record data, windrowing has been the second most commonly applied treatment in the BWBS (second only to burning of slash at the landings). Nearly 17 000 ha in the BWBS have been subjected to this form of mechanical treatment, accounting for over 20% of total area in logged or natural openings (Fig. 15). Most of this area was windrowed. In the past this constituted a one-pass treatment before planting, whereas now it increasingly forms the first phase of a two-pass site preparation treatment (B. Wesleyson, pers. comm.).

Windrowing was perceived to be an effective method of slash reduction as an alternative to broadcast burning, which is considered risky in this area due to persistent winds and relatively dry summer conditions (W. Thorp, pers. comm.).

Windrowing and piling was formerly carried out using tractor-mounted straight (angle) blades. Now brush blades are more commonly used. Prime movers are normally tractors of a D-7 to D-8 size. According to history record information, costs ranged from about $300-600/ha in 1986, with most treatments falling under $400.

Case Study 12 (Appendix 1) is representative of winter windrowing before a second-pass treatment. Windrows are normally oriented east-west to promote more complete burning (D. Renaud, pers. comm.). The orientation of the windrows also controls the orientation of the subsequent second pass, and this may need to be considered. Vegetation control was very poor and average cover of reedgrass was estimated at 60% (Fig. 17).

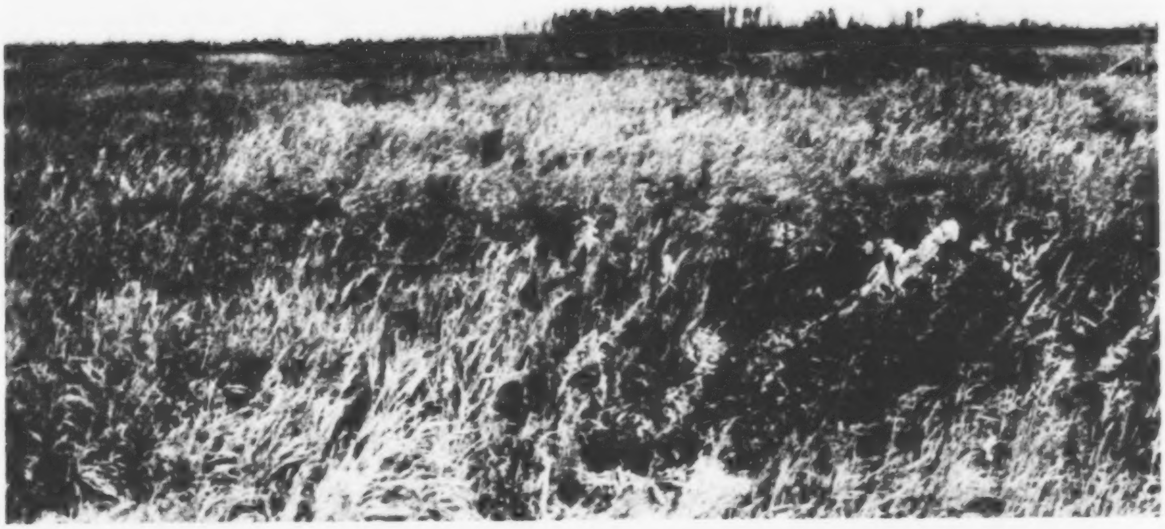

FIGURE 17. Heavy reedgrass competition following rehabilitation of the Osborne Fire, in the Fort St. John Forest District (BWBSe) (Case Study 12, Appendix 1).

5.3.4 SBS

Blade scarification

A number of questionnaire respondents perceived that the advantages of this type of treatment were the availability of equipment and experienced operators. In addition, the treatment was deemed capable of creating planting spots on difficult sites which could not be burned. However, most respondents regarded it as a treatment falling out of favor, primarily because of the limitations listed in Section 5.3.1.

Case Study 3 (Appendix 1) describes an experimental plot established on a blade scarified site in the SBS. The differences between the bladed and unbladed ground was dramatic, with virtually no survival on the latter (Fig. 18). Performance of the planted spruce and lodgepole pine was good, but competition from birch, cottonwood, and aspen was observed. A thick cover of fireweed and reedgrass was observed on the unbladed area. Although soils were coarse-textured (a loamy sand outwash), nutrient deficiencies were not apparent. The conclusion was drawn that freedom from competition and warmer soil temperatures compensated for locally impoverished nutrient status. However, on another similar blade-scarified site, planted spruce was freely growing after 5 years, but overtopped by birch after 10 years (R. McMinn, pers. comm.).

FIGURE 18. An old blade scarification site in the Prince George East Forest District (SBSf). Both spruce and pine have grown well in the scarified trail (left). In contrast, none have survived in the untreated strip. Soils are sandy Orthic Humo-ferric Podzols developed on outwash (Case Study 3, Appendix 1).

V-plows

V-plows in the SBS are frequently used on brush-prone sites with heavy slash which cannot be burned. A number of respondents felt that the best use of V-plows was on sites in which treatment had been delayed following logging, or on backlog sites in which herbaceous or shrubby (<5 m) competing vegetation was present.

It has been suggested that planting on the sides of the berms makes a seedling susceptible to mechanical damage as snow sloughs down (P. Sears, pers. comm.), particularly in areas of heavy snowfall (i.e, Group 1 units). There is also a question of rooting symmetry in older trees (P. Sears, pers. comm.), but this has not been documented.

Brush blades (windrowing and piling)

Questionnaire response on these treatments varied, probably because of the variability in treatment objectives and effectiveness. Some respondents regarded it as a treatment falling out of favor because of its cost and severity; others described it as a most successful treatment. Nearly 12% of the disturbed land in the Prince George SBS was site prepared either by piling or windrowing.

Disc trenchers

Questionnaire respondents indicated that disc trenchers in the SBS were appropriate for mesic and drier ecosystems in which slash loads were moderate or lighter. Slash was perceived to be the major limitation to their increased use.

One mesic site visited in this study, located in the Mackenzie Forest District (SBSj2), had been treated by a passive TTS disc trencher and planted to Douglas-fir. The site was not heavily brushed-in, nevertheless, the seedlings were largely overtopped by herbaceous vegetation. The berm produced was ill-defined and did not provide any respite from competing vegetation. Although the choice of species was probably incorrect (this was a trial), the effects of the trencher were to encourage, rather than set back, vegetation. The creation of a deeper and wider furrow may have provided sufficient planting spots and respite from brush. More robust, powered devices may be more suitable on brush-prone sites.

In the drier parts of the SBS, the disc trenchers were perceived by respondents to be successful treatments, with good planting spot creation. Planters had the option of planting anywhere from the top of the berm (generally ill-defined) to the bottom of the furrow, depending on the drainage and climate of the site.

5.4 Inverting

5.4.1 General considerations

Inverting, as a microsite preparation, overcomes some of the objections of scalping, in that organic matter is conserved and thus continues to contribute to the nutrient pool of the seedling rhizosphere.

The purpose of inversion is to allow a greater amount of heat penetration into the soil, while at the same time conserving nutrients. Operationally, inverting is accomplished by mounding or by moldboard plows or agricultural discs.

5.4.1.1 Mounding

Mounding is accomplished operationally by scooping up a quantity of organic and mineral soil and inverting it. The resulting mound consists of a mineral soil capping resting on a layer of inverted duff. The composition depends on the thickness of duff, the nature of the underlying mineral soil, and the cohesiveness of the vegetation mat, if present (e.g., Sutton 1984b). Mounding implements currently available are the Bräcke mounder, the Sinkkilä HMF scarifier, and the "Ministry mounder", developed by the Silviculture Branch, B.C. Ministry of Forests and Lands. Very recently, small excavators have been used to create large mounds on subhygric and hygric sites, and the Eden relief bedding plow has been used in the BWBS.

Bräcke mounder

The Bräcke mounder consists of a Bräcke scarifier to which a pair of hydraulically operated shovels has been added. The Bräcke has been used throughout the study area, with variable results. One of the main concerns here is its ability to operate properly in the presence of heavy logging slash, and on moderate slopes or wet ground (P. Sears, pers. comm.).

Various modifications, such as number of mattock tines, gear ratios, angle of shovel penetration, and shovel shape and size , can significantly affect the density, size, shape and quality of the mounds produced. Recently, specially designed V-plows for skidders have been developed, which expand the range of sites suitable for Bräcke operation.

Sinkkilä

The mounding action of the Sinkkilä differs from that of the Bräcke Instead of scooping soil with a spade, a pair of robust 4-tine mattock wheels drags mineral and organic material along a 2-m gouge and deposits the mixture at one end. It has been prescribed on sites with duff layers too deep for the Bräcke (H. Krawczyk, pers. comm.).

If soils are poorly coherent, (e.g., sands or loamy sands), soil will sift between the double tines and a mound will not be created (Hedin 1987a). Because the Sinkkilä uses a braking tine to drag a mixture of organics and mineral soil over the surface, occasionally a "jelly roll" effect is achieved (Hedin 1987a) in which the duff and root mat are rolled up, creating an unsatisfactory planting site. This may take place where the duff layer and root mat are very coherent, and the tine is unable to penetrate deeply enough.

The Sinkkilä weighs 3400 kg, which may cause problems on subhygric or hygric sites where soils cannot tolerate heavy traffic. It has also been noted to be mechanically unreliable (N. Crist, pers. comm.). However, as it is a very recent introduction, this should not deter its further testing.

Ministry mounder

The Ministry mounder is a unit that attaches to the ripper parallelogram of a crawler, and employs two shovels that dig into the soil as the unit moves, then flip back to create an overturned mineral mound. Shovel angle and release pressures can be adjusted to suit specific site conditions. The unit was under development by the Silviculture and Engineering branches of the B.C. Ministry of Forests and Lands for 6 years (Hedin 1987b) until it became operational in 1987. The prototype was designed to operate with a D7 prime mover. A modified mounder operating with a D8K crawler uses a separate diesel motor to supply the hydraulics of the mounder, leaving the D8K with adequate power to disperse slash and clear the site (Hedin 1987b).

Effects on seedling performance

McMinn (1985a) indicates that seedling growth on inverted mounds was superior to that in screefed areas, in an experiment monitored over 10 years. Deeper mineral soil cappings may be more effective than shallow cappings (McMinn 1985c). Recent studies suggest that raised mounds experience significantly higher soil temperatures (McMinn 1985a) and may, through accelerated mineralization of nitrogen, promote higher foliar nitrogen concentrations in seedlings (Draper *et al.* 1985).

Furthermore, seedlings planted on mounds have a height advantage over those planted at the ground surface (or those planted in a depression; see Section 5.3). This can be highly important in the face of dense competing vegetation (Draper *et al.* 1985).

Site limitations

Mounds may dry out in some areas. Sutton (1984b) found, in Ontario, that mounds created in cohesive soil were highly resistant to rewetting once they had dried. Further, mounds created in coarse textured soils (sands) had inadequate moisture retention to promote Jack pine seedling growth. He also speculated that the capillary discontinuity caused by the buried duff layer may aggravate moisture stress in the seedling.

Mounds created on coarse (sandy) soils may be subject to wind and rain erosion leading to instability, which may be exacerbated by twisting and swaying of seedlings in the wind (Sutton 1984b). These results suggest that mounders are inappropriate on coarse soils and on fine, cohesive soils.

Deep accumulations of surface organic matter may not be suitable for the mounders. If these layers are deeper than the scoop depth of the spades, no mineral soil is placed on the mound, thereby defeating its purpose. Studies by McMinn (discussed above) indicate that performance in spruce seedling growth improves with size of mineral soil capping. Therefore, mounding spades must be able to reach well into the mineral soil below the overlying duff. However, a V-plow can be used to remove organic matter. In addition, organic mounds may, under certain conditions, serve as suitable planting sites (A. Todd, pers. comm.).

At least some of the problems encountered in the past can be resolved by design modifications and better matching of treatment to site.

5.4.1.2 Moldboard plows

Moldboard plows invert by displacing a layer of organic plus mineral soil onto an adjacent strip. This forms a continuous furrow. Normally, plows have more than one moldboard; thus, one strip of inverted soil is displaced onto undisturbed organic material (creating a double humus layer), but the others displace onto furrows just created by an adjacent moldboard (producing a single humus layer).

Moldboard (breaking) plows of robust design are routinely used for agricultural conversion in the Peace River area. In a study undertaken at the Agriculture Canada Research Farm in Prince George, Grevers and Bomke (1986) found that moldboard plowing of lacustrine soil under grass sod created a more favorable physical environment than chisel plowing or discing. The implement used was a three-bottom Overum breaking plow, and tillage was carried out on a Orthic Gray Luvisol (Pineview Clay Association).

5.4.1.3 Agricultural discs

Discing has an inverting effect and, by exposing mineral soil, should increase the rate of soil warming. It also has a tendency to mix mineral soil and organic matter. Disc cultivation achieves vegetation control by breaking up grass sods and comminuting the root systems of deciduous tree species, achieving an effect akin to mixing. In Alberta, a system of "double discing" has been adopted, in which a second discing takes place after weed invasion has occurred (Coates and Haeussler, in press). The second pass then proceeds at right angles to the original discing, thereby maximizing vegetation control and soil/organic mixing.

Because the use of agricultural discs is limited to relatively stone-free soil and light slash conditions, discing is not a widely used site preparation tool. It has primarily been applied to rehabilitation of aspen and mixed hardwood backlog types in the BWBS, usually as a secondary treatment following windrowing.

5.4.2 BWBS

Mounding implements have been tested on the extensive fine-textured soils in the Peace River area. There is one resident Bräcke mounder machine, and in addition, the Silviculture Branch mounder has been tested. The main limitations of the Bräcke mounder were perceived by questionnaire respondents to be its mechanical unreliability and its unsuitability for sites with heavy slash loads, deep duff layers, and fine-textured cohesive soils. Some of the unreliability referred to may have been due to lack of operator training or familiarity with the machinery.

Total area treated by the Bräcke mounder in the Fort St. John Forest District was dramatically less in 1987 than in previous years, partly because of dissatisfaction with results on fine-textured soils (D. Renaud, pers. comm.).

A common criticism is that mounds are not large enough and do not contain an adequate amount of mineral soil (B. Wesleyson, pers. comm.[illegible] machine operating in the Peace River area was working with a 4-tined mattock wheel. Conversion to [illegible]tined mattock wheel may enlarge mound size (A. Todd, pers. comm.). So far, creation of good raised planting spots has been inconsistent.

However, enlarging the size of the mound will not necessarily alleviate all problems with the mounder. An assessment was made of a site prepared by the Branch mounder, in which a 3-m screef was gouged, producing variable mounds 15-40 cm high. The site was subhygric, with cohesive and imperfectly drained soils (described as a Luvic Gleysol) and a seasonally high watertable. Mounds frequently consisted of discrete clods which, having been raised above the surrounding soil surface, had dried to a cement-like consistency. Planting spot creation was very poor, although it has been argued that overwintering will break down these clods (A. Todd, pers. comm.). Also, planters can break down remaining clods with their boots (L. Bedford, pers. comm.). Clearly, the range of sites suitable for a mounding machine has to be ascertained. Several questionnaire respondents and interviewees considered the mounder to be suited to sites within medium to coarse-textured soils on gentle slopes.

Sinkkilä

The effectiveness of the Sinkkilä as a mounder was monitored by FERIC (Hedin 1987a) on an aspen rehabilitation site near Hudson Hope. In the silt loam soil, 76% of mounding attempts resulted in satisfactory mounds, with generally good contact between the overturned soil mass and the underlying soil. Unsatisfactory attempts were the result of slash, machine malfunction, stumps, and deep duff layers (Hedin 1987a). In some cases, ground contact was inadequate because of the presence of fine slash and debris, a problem common to mounders.

Slash conditions

Slash conditions are commonly reported to be a limitation for the Bräcke mounder, in the BWBS as in the SBS zone. Consequently, it is now being used more and more as a second pass treatment following brush blading or broadcast burning (B. Wesleyson, pers. comm.). On clean sites, lacking thick duff layers, the mounder should have unimpaired operation and may produce excellent planting sites.

Brush control

As a second-pass treatment, the Bräcke mounder may achieve its objective of producing excellent planting spots, but brush or grass control may be as much of a problem as for patch scarifiers. Small mounds with little mineral soil capping are generally not sufficient in areas of intense vegetative competition, such as over much of the BWBS zone (see Case Study 12, Appendix 1), where a reedgrass problem exists. Follow-up weeding or herbicide applications become necessary. On the other hand, mounds with a good mineral soil capping at Iron Creek in the BWBS have so far held back initial vegetation (L. Bedford, pers. comm.). The brush control limitation is hardly peculiar to the Bräcke mounder; rather, it is a problem for most treatments throughout the region.

Planting site selection

Planting site selection can be a problem, depending on the quality of the mounds. Where mounds are perceived to be poor, seedlings may be placed in the depressions instead (e.g., Case Study 12, Appendix 1). This, of course, defeats the purpose of mounding, and on poorly drained sites (common in the BWBS) it makes the seedling vulnerable to flooding and cold soils. However, in parts of the Osborne Fire (Case Study 12, Appendix 1), survival of seedlings planted in the sides of depressions is relatively good, especially when mounding rows run east-west (D. Renaud, pers. comm.). The explanation appears to be that the incidence of frost-heaving is reduced on these shaded, cold sites. In contrast, Haataja (1986) in Finland found excessive frost-heave in seedlings planted on the sloping sides of depressions.

Moldboard plows

The use of a moldboard plow has made good early impressions (W. Thorp, pers. comm.). At Stewart Lake, a heavy-duty 4-bottom breaker plow was used behind a Komatsu D85 crawler. This produced effective inversion. Initial growth of spruce appeared to be good with survival after three growing seasons rated at 80%, despite accelerating competition from reedgrass. The prognosis is that, on this particular site, seedlings have a sufficient headstart such that they can cope with the delayed reedgrass competition and eventually attain free-growing status (W. Thorp, pers. comm.).

One potential problem with use of the breaker plow is that exposure of mineral soil may promote excessive surface wash and erosion. Soils in the Peace River area tend to be vulnerable to erosion (Green and Lord 1978) which may, if allowed to progress on a plowed site, nullify any advantages conferred to planted seedlings.

Sheet erosion at the Stewart Lake trials left a surface crust which provides an inhospitable environment for seeds of deciduous species, but which should not disadvantage outplanted stock (unless the shedding of rainwater from the surface leads to moisture deficits in late summer). Unfortunately, it appears that rhizomes of reedgrass are able to persist through such treatment, but are sufficiently delayed that prompt planting may obviate the need for brushing and weeding (W. Thorp, pers. comm.).

Agricultural discs

Discs have been used in rehabilitation trials at Stewart Lake (W. Thorp, pers. comm.). Preliminary results indicate that discing may be an effective method of setting back competing vegetation, especially following windrowing.

However, the initial freedom from brush may be short-lived, as sprouting from surviving root organs of aspen, in combination with subsequent seeding-in from balsam poplar and willow, returned one site at Stewart Lake to a state of moderate brush competition within 3 years. Additional passes, perhaps at right angles to the initial pass, may be more effective in breaking up root systems, but will not address seeding-in (L. Herring, pers. comm.). The treatment was successful in breaking the sod mat without leading to drastically increased grass cover. It may be particularly effective when combined with a chemical treatment. At Stewart Lake, a heavy-duty Rhome breaking disc, attached to a Komatsu D65 crawler, was used in spring, when frost was still in the ground below about 15 cm (L. Herring, pers. comm.).

Eden relief bedding plow

In the Fort St. John Forest District, an Eden relief bedding plow was used to create planting sites (D. Renaud, pers. comm.). This implement creates a large continuous ridge consisting of inverted and mixed mineral soil and surface organic material. The success of this treatment has not yet been assessed. It has been used more extensively in the Vanderhoof Forest District, and is discussed more fully in the next section.

5.4.3 SBS

The only mounder in common use in the SBS zone was the Bräcke. (However, the Sinkkilä was tested by Westar and Northwood in 1986, and the Ministry mounder was used experimentally in Prince George East Forest District.) Questionnaire respondents generally reported that heavy logging slash, especially in the "wet" biogeoclimatic units, was a serious limitation to the use of the Bräcke mounder. Several indicated that it was mechanically unreliable. A V-plow on an appropriate prime mover may address some of these problems.

The results of trials by McMinn (discussed above) show the biological effectiveness of mounding, particularly in the wetter parts of the SBS. However, many of the studies were carried out on hand-modified mounds. The ability of the mounder to achieve biologically suitable mounds under "operational" conditions was perceived by questionnaire respondents to be inconsistent. On heavy slash sites, the Bräcke is likely to miss mounds (by riding up over debris), or to create an unsuitable mound because debris interfered with the operation. On light to moderate slash loads, however, and on even terrain, the Bräcke has been successful in producing acceptable numbers of planting spots (A. Todd, pers. comm.).

One subhygric to hygric site was visited in the Anzac River area (SBSf, 05b-06) in which Bräcke mounding was observed (Fig. 19). Mound creation appeared to be good, with the number of plantable spots well within the specified limits, despite the presence of a moderate slash load. Raised microsites are important on these sites, because watertables may rise following logging (DeLong *et al.* 1986). On this particular site, excessive rutting was not a limitation, because weather conditions (and thus soil moisture levels) were conducive to machine operation. However, the weight of the Bräcke may pose difficulties in moist conditions.

In another subhygric site visited, Bräcke mounding had been carried out on a fine-textured lacustrine soil (SBSj1, 08b). Mounds appeared to be of poor quality, with inconsistent creation of suitable plantable spots. The mounds had dried to hard clods which, according to Sutton (1984b) in Ontario, may resist rewetting. This is the same problem as had been observed on cohesive lacustrine soils in the Peace River area.

Bräcke mounding is also carried out in drier parts of the SBS. In several sites visited (e.g., Case Study 18, Appendix 1), seedlings were planted in the depressions, rather than on the mounds. This may be appropriate on well-drained sites, but is probably unsuitable on subhygric or wetter sites (see Case Studies 19 and 20, Appendix 1, referring to depression-planting in Leno patches).

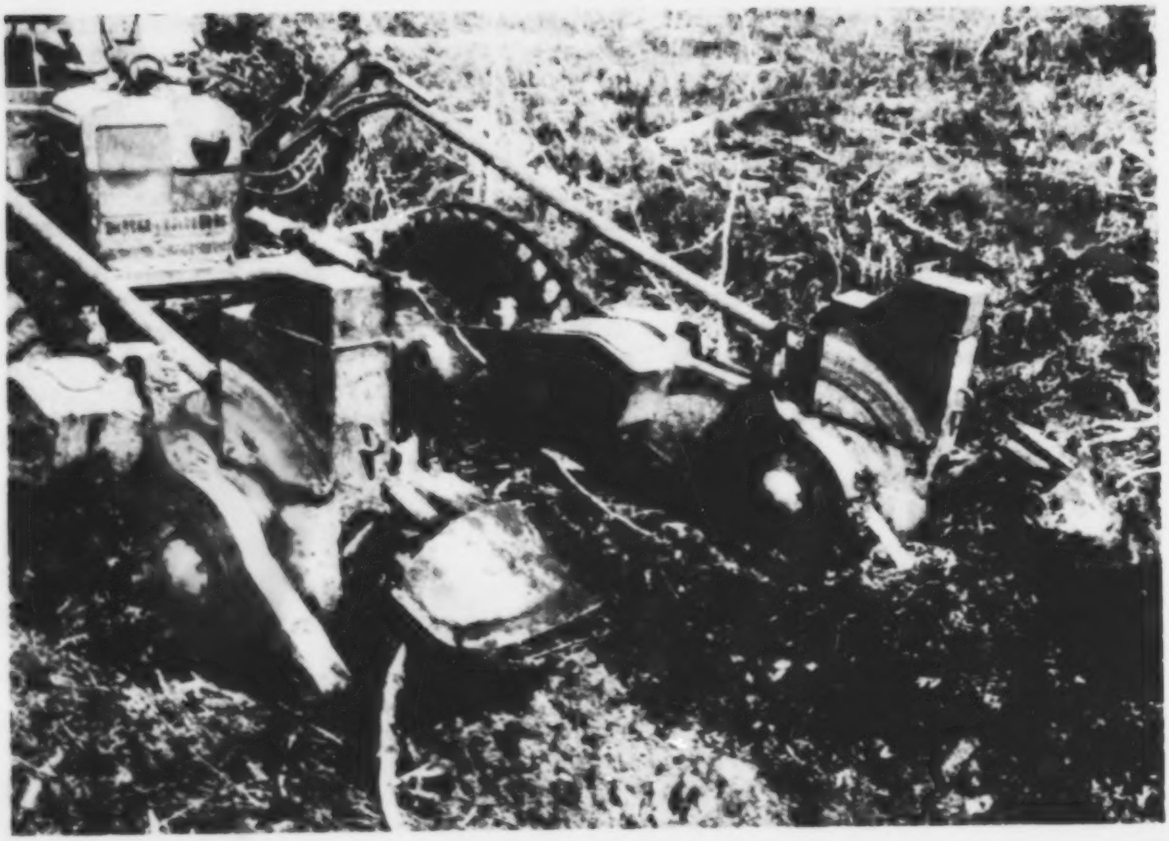

FIGURE 19. Bräcke mounder (I.S.S., Prince George) in operation on a level spruce-horsetail ecosystem in the SBSf. Note 3-tine mattock wheel, allowing deeper penetration of the spades. Operation took place during a dry period.

Sinkkilä

FERIC has monitored the Sinkkilä on a moist sandy loam soil in the SBSe subzone in the Vanderhoof Forest District (Hedin 1987a). Machine malfunction prevented a full assessment. Only 34% of the mounding attempts produced acceptable mounds. Poor ground contact was evident in nearly one-fifth of mounding attempts because of slash, roots, and residuals.

Small excavators (Cat 205 and John Deere 490)

Small excavators with low ground pressure tracks have been used to create mounds. The Cat 205 excavator has been used on wet ground in the Prince George East Forest District in 1986 and 1987 (R. Fahlman, pers. comm.). In such conditions, the excavator may be a suitable alternative to the ripper plow, especially in areas of heavy snowfall where ground freezing cannot be relied upon. Seedlings have been planted on the shoulders of the large mounds created, but it is too early to assess the results of these trials.

Discs:

Eden relief bedding plow

This implement consists of six offset discs, each 45 cm in diameter, arranged in two opposing sets of three. Each set faces inward and overturns a swath of soil towards the center. The result is a "bed" or raised ridge of inverted and mixed soil constituting a continuous planting site. Depending on the soil, the bed ranges from about 25 cm up to 40 cm high, with a width of about 2.4 m (C. von Hahn, pers. comm.). It was introduced to British Columbia only in 1987 (L. Bedford, pers. comm.).

In the Vanderhoof Forest District, about 450 ha have so far been treated using the bedding plow. Initial observations suggest it is appropriate as a second pass treatment on windrowed or piled sites (C. von Hahn, pers. comm.). It performs well on a range of soil types, although on heavier textured soils, penetration was limited and a second pass required. In the future, a ripper plow may be added to shatter the soil beneath the center of the bed, which so far remains intact but buried beneath soil overturned by the discs on either side.

The bedding plow can use a skidder as a prime mover, provided power requirements of 130 kW are met.

Agricultural discs

Agricultural discs are seldom used in the SBS, because they are restricted to relatively slash-free sites with few stones. Where these conditions are met, however, the agricultural discs may be an appropriate rehabilitation treatment. In the Prince George East Forest District, a Rhome breaking disc has been used on recent wildfire sites which have been cleanly windrowed, and on old wildfires which have since been burned again (R. Fahlman, pers. comm.).

5.5 Mixing

Mixing involves bringing together organic and mineral material to form a nutrient-rich medium for seedlin growth. Ideally, mixing should comminute roots and rhizomes of competing vegetation, loosen the soil so as to allow root elongation, and improve the thermal regime of the surface. McMinn (1985d) reported that seedlings planted in a mixed medium showed better growth than did seedlings planted in screefed media. However, he cautioned that mixing must be thorough enough to control vegetation, or the benefits accrued by a superior rooting medium would be lost. Low speed mixing implements may not sufficiently control competing brush.

Madge rotary landbreaker

In the northern Interior, the main mixing implement consists of the Madge rotary landbreaker, which has had limited operational use.

The Madge rotary landbreaker is, in effect, a heavy-duty roto-tiller, which has been used in British Columbia for a number of years in agricultural land clearing. It is a powerful (200-240 kW) machine which is towed behind a prime mover, normally a D6 (L. Bedford, pers. comm.). Rotating tillers mix soil and surface organic material with fine debris, leaving a mulch which forms a potentially excellent seedbed.

The Madge is reported to provide good vegetation control by comminuting root systems, thus eliminating or retarding subsequent sprouting from aspen and other sprouting species (R. McMinn, pers. comm.). In 1987, sites treated in June had still not resprouted by the end of August, in distinct contrast to similar sites sheared and windrowed (D. Renaud, pers. comm.).

Madge Rotoclears are not suited to stony soils (B.C. MOFL 1985), thus their best application is probably on lacustrine soils, both in the BWBS and in the SBS.

In the northern Interior, only one Rotoclear was available for forestry use in 1987.

5.6 Dragging

Dragging is the most commonly applied treatment on recently logged sites where natural restocking is expected. This is particularly true in the Prince George Forest Region, where about 6300 ha were dragged for natural regeneration in 1985-86 (B C. MOFL 1986). It is rarely used as a backlog treatment, but an understanding of its effects may be useful in treating NSR areas derived from unsuccessful dragging.

Dragging is normally accomplished using chains or sharkfin barrels. The objectives are to prepare a suitable seedbed for natural regeneration (normally of lodgepole pine); to achieve a better distribution of cones and therefore germinating seed; and to comminute and align slash so as to accelerate decomposition. Dragging may also bury some cones, thereby reducing the stocking (B. Williams, pers. comm.). In areas where pine cones are serotinous, dragging is expected to bring cones into contact with the surface of the mineral soil, which experiences sufficiently high temperatures to break resin bonds.

Chain dragging was introduced to British Columbia in the early 1960's as an alternative method of slash control to burning (B. Baker, pers. comm.). Its effectiveness as a preparation for natural restocking was, however, soon recognized. In the SBSe2 unit and northern part of the k3, where it is widely practised, it is one of the most successful mechanical treatments because it is used on pine stands on mesic and drier ecosystems which are not inherently brush-prone.

Foresters have now had up to 20 years experience with dragging equipment, and have adapted it to their own particular needs. These adaptations include the number, size and configuration of chains, size and frequency of tines, choice of a "boat" or drawbar, and ballast of barrels or drums in the case of sharkfin dragging. Details regarding the use of dragging equipment are available in Glen (1979), B.C. MOFL (1985), and Coates and Haeussler (1984).

Stocking control

The main problem associated with dragging is stocking control. Overstocked pine is a common problem where seed supply is abundant and conditions are conducive to seed germination. Overstocking can sometimes be alleviated by reducing the number of chains (say from five to three) or barrels during the dragging operation. By delaying dragging 1 or 2 years following logging, lower stocking rates can be obtained (B. Williams, pers. comm.). Heavy dragging equipment on sites with marginal seed counts may result in understocking, since cones may be buried (Case Study 16, Appendix 1).

Although dragging does normally produce a more even distribution of germinants than would occur under no treatment, clumped patterns do occur. However, in Case Study 22 (Appendix 1) dragging resulted in an uneven distribution of pine naturals, not perceptibly different from the distribution in an ecologically similar, but untreated stand (Case Study 21, Appendix 1). This pattern is accentuated on heterogeneous blocks, containing small areas of seepage, steep slopes, or northerly aspects in which natural regeneration may not succeed (A. Todd, pers. comm.; and see Case Study 7, Appendix 1). The result, then, is a predominantly SR block containing NSR patches which, depending on their size and accessibility may be uneconomical to treat (B. Baker, pers. comm.).

Natural regeneration

A number of factors affect the potential for natural regeneration. These include cone serotiny and/or seed viability, cone distribution on the ground (which in turn is affected by logging method and season), and the ecological constraints of the site. Dragging for naturals is relatively uncommon within the SBS units in the Prince Rupert Forest Region. About 6.4% of disturbed forest land in the Prince Rupert SBS was treated by dragging, compared to 16.7% in the Prince George SBS (Fig. 15). Problems with natural regeneration of lodgepole pine in the Prince Rupert Forest Region have been variously attributed to seed viability, species silvics, and climatic conditions. Cone serotiny may become less dependable in the extreme western parts of the study area, for example, in the SBSa subzone (Pojar *et al.* 1984). Westar Timber Ltd., operating largely in the SBSe1 and d units, report unsatisfactory results with dragging and have therefore tried to rely entirely on artificial regeneration (D. Curtis, pers. comm.).

Cone distribution

Cone distribution is usually determined before treatment, either by formal pine cone ground survey or by "walk-through" (B. Baker, pers. comm.). For example, cone and seed counts are high in much of the "pine type" in the SBSe2 (J. Casteel, pers. comm.), whereas counts may be marginal or low in southern portions of the SBSk2 and k3 units, especially where Douglas-fir content increases (B. Baker, pers. comm.). Failure to stratify openings properly according to cone loading has been suggested as a reason for strata of marginally stocked NSR in the southern part of the Vanderhoof Forest District (D. van Dolah, pers. comm.). Strata containing insufficient cones need to be identified and planted, subject to a minimum size constraint. Of course, high cone densities do not ensure success.

Ecological factors that make a site unsuitable for dragging pertain to the degree to which mineral soil can be exposed and warmed, thus breaking resin bonds. North-facing slopes may not receive sufficient insolation for successful dragging (A. Todd, pers. comm.). Thick duff layers impose another limitation, because dragging may not expose sufficient mineral soil. Sites on which this is a problem are normally mesic or wetter, and thus also prone to brush invasion and low soil temperatures resulting from high soil moisture levels. Brush-prone sites are not appropriate for dragging. For example, Herring (1981) found sharkfin barrels to be less effective than the C&H plough in setting back competing vegetation.

Limitations to use

Slash loading and terrain factors restrict the use of dragging equipment. Chains are generally used on openings in which terrain is gentle and unbroken, and slash is light to moderate (J. Casteel, pers. comm.). These are usually associated with mesic to submesic ecosystems. For example, in the SBSe2, dragging is prescribed on ecosystem units (01) Bunchberry-moss, (04) Douglas-fir - subalpine fir, (05) Ricegrass-moss, and (06.1) Pine-black spruce-dwarf blueberry (DeLong *et al.* 1986). Sites with heavier slash loads or deeper duff may require the more drastic treatment of the sharkfin barrels. However, both chains and sharkfin barrels can be adapted to some extent to suit specific conditions by adding or reducing weight, or by changing configurations. Coates and Haeussler (1984) report that duff layers over 10 cm are not suitable for chains, and that 20 cm is the upper limit for sharkfins.

Most dragging equipment is unsuited to slopes greater than about 15%, so where such slopes occur within dragged blocks, they frequently become NSR. Consequently, backlog sites on naturally restocked areas are commonly in the form of isolated patches amongst well-stocked blocks of pine (B. Baker, pers. comm., regarding SBSe1, and e2).

Recommended prime movers vary according to the weight and configuration of the dragging equipment. In general, skidders are used to pull light drags on sites with shallow surface organic layers. More powerful crawler tractors (e.g., D8) are required to pull heavier drags on moister sites. For example, Takla Division of Canfor uses D8-size crawlers for dragging sites in the SBSe2 units, but D7-size crawlers or skidders for dragging in the SBSk2 and k3 units, where duff is generally shallower.

Summer logging

A possible alternative to dragging is to depend on summer logging to disturb the site and expose mineral soil. Although it has been considered a viable prescription (e.g., Pojar *et al.* 1984), especially on submesic and drier sites in which duff layers are thin, it is unpopular because seed distribution remains poor (J. Casteel, pers. comm.).

Furthermore, the move away from hand-falling with line skidders and towards feller/bunchers and grapple skidders has reduced the amount of ground disturbance. Delimbing at the landing rather than at the stump also leaves fewer cones on the site (G. Lloyd, pers. comm.). In the southern Interior, Clark (1984) found that ingress of regeneration following feller buncher/grapple skidder logging took place at the same rate as following conventional logging, but nevertheless he recommended scarification. No respondents or interviewees reported modifying skidding patterns so as to maximize ground disturbance for natural restocking.

Artificial regeneration

About 12% of the total area dragged in the northern Interior in 1985-86 was done to prepare planting spots (B.C. MOFL 1985). Case Study 5 (Appendix 1) represents a recently logged site which was drag scarified using sharkfin barrels to prepare planting spots. Here exposed mineral soil was well distributed, and some degree of mixing of mineral and organic material was achieved.

Herring (1981) reported that sharkfin barrels were effective in producing plantable spots in "light to moderate brush and debris cover", on a backlog site in the Vanderhoof Forest District. The treatment, therefore, may have some application in backlog rehabilitation. Where brush problems are anticipated, sharkfin dragging in conjunction with herbicide spraying may be appropriate.

6 SUMMARY

This report contains a collation of existing practices and experiences relating to backlog rehabilitation in the northern Interior. Information was gathered from questionnaire responses, interviews, field visits, case studies, and literature.

6.1 Perception of Regeneration Problems

Overall, vegetative competition by various brush species (and not just aspen) and low soil temperatures were perceived as the most serious ecological problems. Lack of site preparation or excessive delay in treatment were cited as important silvicultural factors leading to current plantation failure. Immediate planting following site preparation was stressed as the way to improve plantation performance.

Inadequate seedling supply was a major factor contributing to regeneration failure in the past. Although seedling supply and quality is and has been the subject of considerable research and development, many practitioners complained of continuing shortfalls in requests and doubtful quality in stock types. Some were concerned about the explosive increase in seedling production without a concomitant improvement in quality. Despite these complaints, the situation has improved dramatically in the last 10 years.

Many silviculturists stated that current logging should be a higher priority than backlog rehabilitation, and some disagreed with excessive reallocation of silvicultural funds and seedlings from current to backlog treatments.

6.2 Problem Areas

Plantation failures in all regions were disproportionately high on wetter, brush-prone ecosystems or steep, north-facing slopes. Treatment of these sites is difficult because of site sensitivity to heavy traffic, rough terrain, deep duff, and dense or high stumps. Backlog sites of this type are dispersed throughout the study area, often in small (< 20 ha) patches which may be uneconomical to treat. There is a need to develop reliable equipment that can handle these conditions. Existing equipment may be inappropriate, too expensive, or mechanically unreliable. Inoperable areas need to be identified in a coherent rehabilitation or microsite preparation plan, and appropriate treatments prescribed.

Regeneration in the Peace River area was deemed to be particularly difficult because of the combination of climatic factors and the unique brush problems. Rehabilitation policy for hardwood stand conversion will be profoundly affected by the recent introduction of a manufacturing plant using aspen.

Dragging for natural regeneration of pine on current sites is inconsistent in many parts of the SBSd, e1, and southern parts of the k subzone. In other areas, parts of blocks otherwise suited to natural regeneration may not "catch" because of low soil temperature, thick duff, or other factors. Again these areas need to be identified and treated accordingly.

6.3 Treatment Successes and Failures

No treatment was accorded universal success or failure. Personal experiences with treatments were usually confounded by specific site conditions, stock quality, mechanical reliability, operator experience, and conditions prevailing during planting. Assessments of established plantations did not yield consistent conclusions on treatment effectiveness. Plantations may fail for innumerable reasons, only one of which is microsite preparation. Table 4 lists site preparation treatments, associated problems (as indicated by silviculturists), and an array of possible options to eliminate or mitigate them.

Prescribed fire is generally held to be the most effective site preparation tool on current sites, but there are many constraints: control problems in some areas (such as the Peace River and Prince Rupert Forest Region) and narrow burning opportunities in other areas (SBSj1, j2, f, and o). Nevertheless, scientifically applied burning should be encouraged on appropriate sites, especially where mechanical treatments are inefficient or degrading to site productivity. Extension and demonstration of the most up-to-date prescribed fire techniques are recommended, especially in areas in which fire is under-used. Prescribed fire on backlog sites is an option not yet fully explored.

The choice of mechanical equipment for rehabilitation also varies between regions. The range of potential equipment is constantly changing, but availability is a continuing problem. Further extension and demonstration of modern equipment and techniques is necessary. Encouragement of communication between licensee, district, and regional Forest Service silviculturists is also required. The MOFL Silviculture Branch, under the FRDA program, is already active in this area; and the Northern Silviculture Committee has stimulated much exchange of ideas to date. Regional silviculture staff routinely meet to exchange ideas. Despite this exchange, there was considerable disparity in perceptions and practices, in part due to different ecological conditions.

The development of equipment that will operate in heavy slash is the most pressing need. Over-reliance on Scandinavian designs which are not suited to Canadian conditions has been blamed for the lack of suitable machinery. Heavy logging slash reduces the opportunity and effectiveness of specialized equipment, such as mounders, disc trenchers and patch scarifiers. These limitations force managers to rely on more drastic measures. New developments for coping with slash, such as V-blades mounted on skidders, or more robust, powered disc trenchers (e.g., Donaren) have not yet been widely tested or demonstrated.

Perhaps the main problem with site rehabilitation techniques is that experience is so recent. Long-term implications are unknown. Although the effects of treatments carried out 10 years ago can now be assessed, those treatments may no longer be in vogue. For example, many failed or failing plantations were established without any microsite preparation. This is an important historical cause of backlog land, but is no longer a major factor, since most sites are now treated.

Rehabilitation throughout the study area consists of brush clearance followed by microsite preparation. Under certain circumstances, either one of these phases may be carried out in one operation. For example, in some backlog sites, V-plows prepare planting sites and at the same time provide a measure of brush clearance. Sometimes an aerial herbicide spray will be used to clear brush, followed by fill-in planting without any specific microsite preparation.

The use of herbicides varies dramatically across the study area. Increased use of chemicals appears to be necessary to achieve backlog rehabilitation goals. One limitation is public opposition which is, to some extent, manifested by the lengthy permit approval process and reluctance of some to use herbicides. Perhaps a greater emphasis on ground applications, where feasible, might overcome this problem. Machine-mounted sprayers, possibly integrated with site preparation equipment (e.g., the Bräcke herbicider) offer exciting opportunities for development.

TABLE 4. Problem summary

Treatment	Problem	Options/recommendations
1. Mounding (Bräcke)	a) limited by heavy slash	i) avoid sites with heavy slash ii) use as a secondary treatment following shearing and windrowing or broadcast burning iii) equip prime mover with suitable slash dispersing device

TABLE 4. Continued

	b) limited by trafficability on moist sites	i) schedule operation at driest time of season ii) use wide tracks or tires iii) identify and avoid poorly trafficable areas
	c) ineffective in deep duff	i) design changes to allow deeper penetration ii) identify and avoid such areas iii) plant on duff mounds on trial basis (more research required)
	d) poor mounding on fine-textured soil	i) determine optimum soil moisture or consistency for best results ii) design changes to allow better penetration in dry soils iii) check effectiveness of overwintering in breaking down clods
	e) insufficient mound size	i) design changes to allow deeper penetration or increase scoop size
	f) inadequate brush control (on brush prone sites)	i) plant as soon as possible with large stock on brushy sites ii) develop spray attachment iii) backpack or aerial spray, pre- or post-planting iv) ensure large mounds with good mineral soil capping
2. Patch Scarifiers	a) creates poorly drained depressions	i) identify and avoid poorly or imperfectly drained sites ii) plant on edge of patch
	b) exposes subsoil which may be unfavorable for root growth	i) identify and avoid such soils ii) plant on edge of patch
	c) patches susceptible to frost-heaving	i) avoid fine-textured and silty soils ii) aim for minimal scalping depth (ideally Ah horizon) iii) plant on southern (shaded) edge (needs more research)

TABLE 4. Continued

	d) patches too small to provide brush control	i) do not prescribe on brush-prone sites ii) plant large stock immediately iii) develop herbicide spray attachment iv) prescribe pre- or post-planting chemical treatments
	e) does not cope with slash	i) avoid sites with heavy slash ii) use as a secondary treatment iii) equip prime mover with suitable dispersing device
3. Disc Trenchers	a) promotes competition on brush-prone sites (does not comminute roots except in trench)	i) do not prescribe on brush-prone sites ii) plant with large stock as soon as possible iii) develop spray attachments iv) prescribe additional chemical treatments
	b) does not cope with heavy slash	i) avoid sites with heavy slash ii) equip prime mover with V-plow iii) use as secondary (2nd pass) treatment iv) powered trenchers may have better capability
	c) ineffective on deep duff	i) avoid sites with deep duff ii) use equipment with down-weighted discs (e.g., TTS Delta)
	d) grass sod may flip back	i) avoid use on intact grass sods ii) apply greater down-pressure, if possible
4. Moldboard Plows and Discs	a) unsuitable for stony soils	i) avoid stony soils: prescribe on lacustrine soils
	b) may accelerate erosion	i) operate along contour ii) avoid slopes over 10-15%
	c) not effective in slash	i) use as second pass ii) equip prime mover with V-plow

TABLE 4. Continued

	d) not effective on uneven terrain	i) avoid uneven terrain
	e) may not control reedgrass (under certain conditions)	i) plant immediately to large stock ii) prescribe pre- or post-planting chemical treatments
5. Ripper Plow (in frozen ground)	a) trail is too narrow and does not create suitable planting spots	i) design changes to increase displacement ii) use double plows (?)
	b) inadequate brush control (especially reedgrass)	i) plant as soon as possible with large stock ii) prescribe chemical treatments iii) use robust double moldboard design
	c) breakdown in soil structure in spring	i) avoid hygric and wetter sites ii) orient trails along slope to effect drainage
6. V-plows	a) trails susceptible to frost-heave	i) do not plant on compacted trails ii) plant on shaded edge (?) iii) avoid fine-textured or silty soils
	b) excessive gouging and exposure of subsoil	i) close supervision ii) employ skilled and/or experienced operators iii) avoid steep slopes and/or broken terrain
	c) excessive rutting, compaction or site degradation	i) avoid soils sensitive to heavy traffic ii) avoid steep slopes and/or broken terrain iii) schedule operation when soil is able to tolerate heavy traffic
	d) exposed soils later prone to seeding-in to brush	i) avoid plowing if alder/willow/poplar/birch seed source is near ii) plant pine if listed as alternative
	e) snow sloughing and weight on edge-planted seedlings (?)	i) plant high up on berm (if brush control is adequate) ii) plant large caliper stock iii) avoid treatment in high snowfall areas (?)

TABLE 4. Continued

	f) excessive brush between trails and overtopping of seedlings	i) do not prescribe for backlog rehabilitation if brush >3 or 4 m ii) orient trails north-south
	g) limited by stumps	i) avoid sites with high stump density
	h) erosion potential	i) avoid on erodible soils ii) dip and dive where necessary iii) contour trails on erodible soils
7. Piling and Burning	a) excessive mineral soil exposure	i) close supervision ii) avoid up-rooting stumps iii) avoid poorly traffic-sensitive soils iv) schedule operation for period when soil is able to tolerate heavy traffic v) avoid on steep (>30%) slopes
	b) not enough mineral soil exposure (insufficient planting spots)	i) close supervision ii) prescribe 2nd pass treatment iii) plant with large stock as soon as possible iv) prescribe herbicide treatment
	c) difficult to burn piles or windrows to specs	i) do not burn piles ii) bunch- or spot-pile iii) use heavier machinery iv) winter pile, burn next summer or fall
	d) difficult to treat entire block	i) identify inoperable areas and prescribe appropriate treatment (e.g., plant immediately with large stock) ii) design block and logging so as to allow broadcast burn option (if possible)
8. Dragging (Sharkfin)	a) difficult operation in heavy slash	i) do not prescribe in areas of heavy slash ii) match drag configuration to prime mover iii) equip prime mover with V-plow iv) schedule operation for period when soil is able to tolerate heavy traffic

TABLE 4. Continued

	b) does not provide sufficient brush control	i) do not prescribe on brush-prone sites ii) apply chemical treatment iii) plant immediately with large stock
9. Broadcast Burning (Current Sites)	a) risky	i) take max. precautions in high risk situations (e.g., wide fireguards) ii) develop skills and experience iii) extension and demonstration
	b) low impact on moist ecosystems	i) delimit relatively homogeneous blocks (e.g., avoid burning N-facing slopes along with S-facing ones) ii) hot summer burn where possible iii) prescribe 2nd pass treatment
	c) low impact if delayed	i) do not delay ii) brown and burn iii) prescribe 2nd pass treatment
	d) promotes aspen suckering	i) do not prescribe where aspen residuals are common ii) apply pre-harvest hack and squirt iii) post-logging chemical treatment
	e) potential site productivity loss (long-term)	i) do not prescribe on sensitive ecosystems ii) try to achieve target impacts iii) fertilize at planting on over-burned sites iv) more long-term and historical research is required

6.4 Backlog Classification

In this report, backlog land has been classified into "types", first on the basis of the nature of disturbance (e.g., fire or logging), then further by vegetation structure and seral stage. The classification does not yet account for soil type or ecosystem association. It is an interim classification which requires further review and modification.

6.5 Examination of History Records System

The History Records System (HRS) of the Silviculture Branch was used to estimate the areal extent of current and backlog NSR land in the SBS and BWBS zones in the northern Interior. Site preparation methods were also enumerated.

Frequently, site preparation method was not properly listed on history files. More detailed information regarding site preparation must be entered, along with subzone, variant, and ecosystem association, onto the form. Development of new site preparation forms and greater implementation of Pre-Harvest Silvicultural Prescription Forms (FS 711) will aid in the future documentation of establishment data.

6.6 Rehabilitation Prescriptions

The development of site-specific rehabilitation prescriptions was beyond the scope of this project. Much more work needs to done in this regard. Rehabilitation prescriptions need to be worked out in conjunction with prescriptions for mechanical site preparation (e.g., Coates and Haeussler 1984) and for the use of prescribed fire (e.g., Vihnanek and Feller 1985). Furthermore, recommendations must be developed in close consultation with local silvicultural experts.

6.7 Priorities for Research

1. Detailed studies of the ecology of specific site preparation treatments (e.g., mounding and mixing). Studies are already under way (e.g., Draper *et al.* 1985). More research is needed to address the degree of soil warming, frost-heave, root penetrability, and nutrient supply inherent in different microsites. In particular, further research is needed to tie microsite selection to prevailing climatic regimes.

2. Continued research into mounding, particularly into its effectiveness in different soil types. There have been conflicting reports (e.g., McMinn 1985c cf. Sutton 1984b), especially in regard to the creation and longevity of mounds on both fine-textured (lacustrine) and coarse-textured (sandy) soils.

3. Development of site preparation equipment, so that operational treatments can achieve biological objectives. This includes further development of mounding machines which create an appropriate size, shape and quality, and mixing machines which can economically mix mineral with organic soil on a wider range of site conditions than at present.

4. Vegetation control effected by different mechanical site preparation treatments. This is difficult to assess because of variability in ecosystem, mechanical treatments, and operator skill. Such studies are particularly needed for V-plow and blade scarification, which are still being heavily relied upon in some districts, for use on brush-prone sites.

5. Herbicide applications. There is a pressing need for more intensive research into herbicide effectiveness. Emphasis should be placed on spot or ground spray, or on integration with mechanical site preparation. There has been a paucity of research on environmental or wildlife interactions with herbicides in British Columbia. This restricts the conviction of our reassurances to the public (and ourselves). Existing FRDA projects investigating herbicides (Projects 1.2 and 1.3) are on-going in the northern Interior.

6. Use of prescribed fire in rehabilitation. This research is currently under way by the CFS (Taylor *et al.* 1986), the University of British Columbia (Blackwell *et al.* 1986), and the various Research sections of the B.C. Ministry of Forests and Lands (Trowbridge *et al.* 1986).

7. Further studies on species selection. It has been suggested that some districts are planting too much spruce, and that fears of pine being "off-site" are unfounded. More research is warranted. Also at issue is the acceptability of subalpine fir in certain ecosystems across the SBS zone.

8. Fertilization of newly established spruce plantations. Recent research suggests that newly planted spruce in the northern Interior may be suffering from serious nutrient deficiencies, especially iron, copper and nitrogen (Ballard 1984). If so, operational fertilization of young plantations, possibly at the time of site preparation, is worth a closer look.

9. Continued monitoring of the nutrient status of young pine and spruce. Especially following fire, site nutrient loss can be significant, but there are no data on the effect of this loss on growth. More information on the long-term implications of site treatments (including fire) may affect their application.

10. Cost-benefit studies of the rehabilitation of different backlog types. This will aid in the development of rehabilitation priorities.

11. Continued monitoring of all rehabilitation practices, including brush clearance and microsite preparation. In the future, historical assessments should be made easier by properly documenting all aspects of rehabilitation and establishment.

12. Studies on site degradation resulting from rehabilitation, particularly in regard to drastic mechanical treatments such as V-plowing or piling and burning. These should include investigations of soil compaction, structural deterioration (resulting from rutting or loss of organic matter), nutrient depletion and erosion.

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APPENDIX 1. Case studies

CASE STUDY 1.

Site Data

DISTRICT:	P.G. West	SOIL TEXT:	Loam
LOCATION:	Summit Lake	ASPECT:	SW
BEC UNIT:	SBSe2	GRADIENT:	0-10 Complex
ECOSYSTEM:	01 Mesic	ELEVATION:	914

Silvicultural Data

SPECIES:	Sx planted (Pl naturals)	LOG. METHOD:	Skidder, Summer 1977
SEAS/YR:	?/82	SITE PREP:	Burn landings only
STOCK:	unknown		

Performance

AVERAGE HEIGHT (cm):	Sx 42.5, Pl 230	VIGOR:	Sx good, Pl good
STATUS:	Mostly SR		

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Epilobium angustifolium	7	66	100
Rubus parviflorus	4	17	80
Rubus idaeus	5	15	80
Veratrum viridus	12	35	80
Populus tremuloides	5	400	20
Betula papyrifera	12	40	20

History

Logged in summer, 1977. No site treatment except spot piling at landings.

Site Impact

Sufficient mineral soil exposure (estimated at about 20%) created during logging to allow some natural pine in-filling. Duff layer 5-8 cm, relatively intact, except where disturbed by skidder. Light to medium logging slash may have restricted opportunities for broadcast burning.

Brush Problems

Brush competition variable (total cover varies from 70-100%) and severe in places. Species not listed included *Lonicera involucrata, Ribes lacustre, Sorbus sitchensis*, and *Populus balsamifera*. Vegetation displays very clumped distributions. Birch and aspen are up to 4 m tall. Residual aspen have formed dense clonal colonies covering an estimated 10-15% of the block.

Assessment

Heterogeneous block, estimated 20-30% NSR. Spruce seedlings vigorous but fairly slow growing (leader growth avg. 8 cm). Younger pine seedlings dramatically out-competing spruce. Subhygric sites bordering depressions have no surviving seedlings. Some seedlings deformed by fallen fireweed stems.

Implications

Delayed and/or inappropriate treatment may lead to poor growth performance of spruce seedlings. Reasons are: 1) lack of appropriate site preparation to expose mineral soil and create suitable microsites; and 2) delay between logging and planting (4-5 years). Residual aspen and suckering may also be a problem requiring herbicide application either before harvest or after.

CASE STUDY 2.

Site Data

DISTRICT:	P.G. West	SOIL TEXT:	Sandy Loam
LOCATION:	Summit Lake	ASPECT:	NE
BEC UNIT:	SBSe2	GRADIENT:	5-15 Complex
ECOSYSTEM:	01 Mesic	ELEVATION:	884

Silvicultural Data

SPECIES:	Sx planted	LOG. METHOD:	Skidder, Winter 1977
SEAS/YR:	?/80	SITE PREP:	Broadcast burn 1977 V-plow 1980?
STOCK:	?		

Performance

AVG. HEIGHT (cm):	Sx 23	VIGOR:	Sx fair
STATUS:	Partly SR		

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Rubus parviflorus	12	25	100
Rubus idaeus	5	18	60
Athyrium felix-femina	3	30	60
Cinna latifolia	3	120	40
Epilobium angustifolium	2	50	40

(Plots fell in V-plow tracks)

History

In this site, 72 ha were burned the summer following winter logging, but not planted. A further 12 ha were logged in 1979. In 1979 or 1980, the site was prepared by V-plow operating approximately along contours. Spruce was planted in 1980, mostly in tracks or near the edges of the trail. Logging slash was fairly heavy.

Site Impact

The burn was relatively intense and little duff remains; nevertheless, brush has re-invaded heavily the inter-trail area after 9 years. The treatment was fairly harsh: in places the trail has displaced 40 cm of soil.

Brush Problems

Vegetation control in the trails remains good after 6 years.

Assessment

Many seedlings were placed in compacted tractor ruts, or close against north-facing edges of the trail. These seedlings are growing poorly, averaging only 23 cm in height after 6 years (although 1985 leader growth averaged 7 cm, suggesting an improvement over previous years). Slight chlorosis is evident in some cases. Seedlings planted in the middle of the trail, between tractor ruts, appear to be robust and healthy, but again with rather poor height growth.

Implications

Poor microsite selection following V-plow treatment may lead to slow growth of spruce seedlings. Tractor ruts and north-facing slopes are unsuitable microsites. Trail orientation should be north-south wherever feasible, to avoid such shaded edges. Deep rutting and gouging may result from operation during wet periods which, on mesic and subhygric sites, should be avoided if possible.

CASE STUDY 3.

Site Data

DISTRICT:	P.G. East	SOIL TEXT:	Fine to Medium Sand
LOCATION:	MacGregor	ASPECT:	N/A
BEC UNIT:	SBSf	GRADIENT:	Flat
ECOSYSTEM:	01.2a Mesic	ELEVATION:	?

Silvicultural Data

SPECIES:	Sx and Pl planted	LOG. METHOD:	?/74
SEAS/YR:	?/1975	SITE PREP:	Blade scarification
STOCK:	Sx plugs ?/Pl 2 + 1BR		

Performance

AVG. HEIGHT (cm):	Sx 400	VIGOR:	Sx good Pl good
STATUS:	Partly SR		

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Betula papyrifera	5	400	100 trail
Populus balsamifera	5	400	100 trail
Populus tremuloides	2	400	80 trail
Salix	5	200	80 trail
Epilobium angustifolium	70	140	100 between
Calamagrostis canadensis	15	180	80 between

History

This is an experimental plot established by R.G. McMinn in 1975 (ES 13). The intent was to compare growth of Sx and Pl on bladed and unbladed sites.

Site Impact

Blade scarification apparently removed most surface organic material which, in this sandy outwash site, was concentrated in a shallow surficial layer. Between trails, surface organics were left relatively intact. Exposed mineral soils are friable, and so do not hinder root penetration (except below about 20 cm, where minor ortstein formation may be encountered).

Brush Problems

Bladed sites support about 30% brush cover, consisting mostly of deciduous trees which have seeded-in to bare soil following disturbance. These species may eventually overtop the more slowly growing spruce. Unbladed sites consist of 100% brush cover, dominated by fireweed nearly 1.5 m tall.

Assessment

Survival on unbladed sites after 11 years is nil. In contrast, survival is high on bladed trails. Despite the apparent impact of blade scarification on the coarse soils, growth on bladed trails is promising.

Implications

Drastic treatments may effectively set back competing vegetation. Following such treatments, brush invasion is slow and planted seedlings may be free-growing during the first 10 years or so. This freedom, combined with warmer soil temperatures, may compensate for any reduction in local site nutrient status. Untreated areas suffer from heavy brush competition in combination with low soil temperatures, which slow seedling growth.

CASE STUDY 4.

Site Data

DISTRICT:	P.G. East	SOIL TEXT:	Sandy Loam
LOCATION:	Wansa Lake	ASPECT:	SE
BEC UNIT:	SBSj1	GRADIENT:	10-15%
ECOSYSTEM:	06 Mesic to Submesic	ELEVATION:	914

Silvicultural Data

SPECIES:	Pl and Sx	LOG. METHOD:	Grapple, Winter 1979
SEAS/YR:	81,82,83,84 Jun/Jul	SITE PREP:	Broadcast burn 1980?
STOCK:	Sx ?, Pl ?		

Performance

STATUS:	SR	VIGOR:	Pl good
AVG. HEIGHT:	Pl 74 cm Sx ?		

Competing Species

	AVG COVER %	AVG. HEIGHT cm	FREQUENCY %
Epilobium angustifolium	17	85	100
Rubus parviflorus	11	30	100
Rubus idaeus	15	28	100
Spiraea betulifolia	5	26	100
Ribes lacustre	5	32	80
Cinna latifolia	1	75	60

History

This area was logged by grapple skidder in the winter of 1979. Broadcast burning appears to have been carried out in the following summer, and planting took place in each of 4 successive years. Spruce was planted in mesic sites above the landing, and pine on steeper, submesic sites below the landing. This site is typical of the large number of blocks for which complete treatment information is lacking.

Site Impact

Mineral soil exposure is minimal, and the remaining duff layer, up to 3 or 4 cm thick but generally thinner, is more or less intact. It consists largely of charcoal and mineralized humus which seems to be partly incorporated into the upper few centimetres of the mineral soil. The broadcast burn was correctly executed, with adequate duff reduction but apparently minimal site degradation.

Brush Problems

Although too early to tell, it would appear that brush competition is not threatening this plantation.

Assessment

Pine was planted in 1982, and the 4-year-old seedlings are performing well with an average leader growth of 15 cm. It is not known why successive plantings were needed. No spruce seedlings were observed in the portion of the block assessed.

Implications

Broadcast burning, following winter logging, can be a successful treatment for preparing a site for planting. Appropriate impacts can control brush competition, as well as providing suitable planting microsites for optimal growth of pine.

CASE STUDY 5.

Site Data

DISTRICT:	P.G. East	SOIL TEXT:	Sandy Loam
LOCATION:	Grizzly Lake	ASPECT:	N/A
BEC UNIT:	SBSj1	GRADIENT:	0-3%
ECOSYSTEM:	06 Submesic	ELEVATION:	914

Silvicultural Data

SPECIES:	Sx and Pl	LOG. METHOD:	Grapple, Winter 1979
SEAS/YR:	83 May	SITE PREP:	Sharkfin scarification 1980 for planting (Pl?) Broadcast burn?
STOCK:	Sx ?		

Performance

STATUS:	SR	VIGOR:	Sx good
AVG. HEIGHT:	Sx 85		

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Epilobium angustifolium	9	84	100
Rubus idaeus	11	26	100
Sambucus racemosa	2	62	60
Ribes lacustre	1	13	80
Calamagrostis canadensis	5	70	20

History

This site seems to have been burned, although no record of burning is evident in the opening file. The recorded treatment is sharkfin dragging.

Site Impact

The site preparation treatment has been effective in achieving some degree of mixing of mineral with organic soil. The remaining duff layer is 5-7 cm thick, with incorporated woody material. The microtopography is highly heterogeneous, and exposed mineral soil is well distributed throughout the site.

Brush Problems

Brush competition is low.

Assessment

Spruce seedlings have performed well in the 3 years since out-planting, although many seedlings appear slightly chlorotic. Leader growth averages 20 cm. However, the chlorotic appearance of many seedlings is a potential problem. Chlorosis may have been due to excessive site disturbance. Alternatively, the soil type, derived probably from a moderately coarse-textured fluvioglacial terrace, may be inherently low in fertility. Height growth does not appear to have been affected to date, but may be later.

Implications

Burning, followed by sharkfin dragging, may result in nutrient depletion to which spruce is particularly sensitive. However, the combination provides good brush control on submesic sites.

CASE STUDY 6.

Site Data

DISTRICT:	Mackenzie	SOIL TEXT:	Sandy Loam
LOCATION:	Gataiga Creek	ASPECT:	N/A
BEC UNIT:	SBSj2	GRADIENT:	0-3%
ECOSYSTEM:	05 Subhygric	ELEVATION:	762

Silvicultural Data

SPECIES:	Sx	LOG. METHOD:	Skidder , Summer 1975
SEAS/YR:	Fall/85	SITE PREP:	Windrow and burn for regen. 1976, C&H plow rehab. 1984
STOCK:	Sx 1 + 0 PSB 211		

Performance

STATUS:	NSR (Current)		
AVG. HEIGHT:	Sx 23	VIGOR:	Sx poor

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Equisetum arvensis	22	27	100
Epilobium angustifolium	10	38	80
Lonicera involucrata	7	55	60
Cornus sericea	3	55	60
Calamagrostis canadensis	50	73	40
Alnus incana	10	400	20

History

This site has a long history of failure. According to the opening file, it was windrowed in 1976 for naturals, a treatment doomed to failure. In 1984 it was treated with a C&H plow and planted to Sx the following fall.

Site Impact

Although the soil contains a 15 cm Ah horizon, the plow frequently gouged into the underlying Bg horizon. Severe rutting was evident in places.

Brush Problems

The brush hazard is very high on this site, but the plowed trails were largely free of competing vegetation, except for horsetail and fireweed.

Assessment

Microsite selection was poor, with many seedlings planted in low-lying positions within the trail. Some of these microsites were still flooded at the end of July. Many seedlings were suffering from shoot die-back and severe chlorosis. The plantation will likely attain NSR status. If current, this site would have benefited from a broadcast burn with high impact rank, followed by a mounding treatment. However, because this was a previously windrowed backlog site, burning was probably not an option.

Implications

Poor microsite selection following V-plowing is a frequent cause of failure: seedlings placed in the trail itself will be killed by spring flooding or doomed by poor root egress in compacted tractor ruts. Seedlings planted on the trail edges may be relatively vigorous.

CASE STUDY 7.

Site Data

DISTRICT:	Mackenzie	SOIL TEXT:	Gravelly Sandy Loam
LOCATION:	Buth Creek	ASPECT:	Variable
BEC UNIT:	SBSj2	GRADIENT:	0-15%
ECOSYSTEM:	01.2 Mesic	ELEVATION:	914

Silvicultural Data

SPECIES:	Sx, Pl	LOG. METHOD:	Wheel skidder, Winter 1977
SEAS/YR:	Jun/79	SITE PREP:	Windrow and burn for planting Fall 1977
STOCK:	Sx ? Pl ?		

Performance

STATUS:	partly SR		
AVG. HEIGHT:	Sx 0 cm Pl 130 cm	VIGOR:	Pl good Sx dying

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Rubus parviflorus	13	34	100
Rubus idaeus	15	34	100
Ribes lacustre	3	41	100
Lonicera involucrata	5	92	80
Epilobium angustifolium	9	60	80
Cornus sericea	14	103	60
Viburnum edule	4	88	60

History

This variable site was windrowed in the fall following winter logging, then a portion was planted to Sx 2 years later.

Site Impact

Soil disturbance was such that natural regeneration of pine was successful in about two-thirds of the site.

Brush Competition

Planted spruce was mostly overtopped by competing vegetation by 1986. Brush competition is patchy. In places, aspen clones have completely eliminated spruce and pine. Portions of the plantation are now NSR because of brush competition.

Assessment

North-facing slopes planted to Sx are now NSR; a pine crop did not establish despite plentiful cones. Deeply exposed mineral soils, especially along skidtrails, are now heavily colonized by Sitka alder (*Alnus viridus*). Where freely growing, Pl is growing reasonably well with an average leader growth of 30-35 cm. Residual balsam is abundant throughout, but much of it has been damaged in logging. Residual aspen is a problem here as in Case Study 1.

Implications

Heterogeneity of blocks renders treatment prescription difficult.

North-facing slopes in chain-dragged blocks commonly fail because natural pine did not "catch." These difficult sites need to be identified early, and either more drastic site preparation treatments or follow-up herbicide actions prescribed.

CASE STUDY 8.

Site Data

DISTRICT:	Mackenzie	SOIL TEXT:	Very Gravelly Loamy Sand
LOCATION:	Buth Creek	ASPECT:	Variable
BEC UNIT:	SBSj2	GRADIENT:	0-15%
ECOSYSTEM:	02 Subxeric	ELEVATION:	914

Silvicultural Data

SPECIES:	Pl	LOG. METHOD:	Wheel skidder, Winter 1977
SEAS/YR:	June/79	SITE PREP:	Windrow and burn for planting, Fall 1977
STOCK:	Pl ?		

Performance

STATUS:	SR		
AVG. HEIGHT:	Pl 242 cm (7 yr)	VIGOR:	Pl excellent

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Betula papyrifera	3	103	100
Spiraea betulifolia	3	38	100
Hieracium albiflorum	3	40	100
Epilobium angustifolium	2	35	100
Anaphalis margaritacea	1	40	100
Alnus viridus	21	160	80

History

This site is part of the same opening described in Case Study 7. Logged and spot-piled in 1977, this subxeric to submesic site was planted to Pl in 1979.

Site Impact

Spot-piling was drastic, removing most of the surface organics and causing much mineral soil exposure. In some places, burning of piles appears to have escaped resulting in local "broadcast burns."

Brush Problems

There is virtually no brush on this site, except for patches of alder (*Alnus viridus*), but these do not significantly interfere with pine performance.

Assessment

All planted seedlings are freely growing, and in places are shading out subsequently established naturals. Leader growth averages 54 cm. Stumps from previous stands indicate excellent diameter increment up to 30-40 years, then a fairly dramatic drop-off. There is concern about the long-term productivity of this site. Reductions in growth may occur considerably before the 30- to 40-year age indicated in the previous stand. A conservative approach to managing these sites is probably wise. The choice of spot-piling is questioned. Depending on the slash load (which was probably light) no mechanical site prep may have been necessary at all.

Implications

On sensitive sites, microsite preparation should conserve the nutrient capital. It should be carried out carefully, so as to maintain existing surface organics. In the past, site degradation has occurred where escaped slash burns consumed the entire remaining duff layer.

CASE STUDY 9.

Site Data

DISTRICT:	Mackenzie	SOIL TEXT:	Gravelly Loamy Sand
LOCATION:	Buth Creek	ASPECT:	South
BEC UNIT:	SBSj2	GRADIENT:	15%
ECOSYSTEM:	01.1 Mesic	ELEVATION:	910

Silvicultural Data

SPECIES:	Sx,Pl	LOG. METHOD:	Wheel skidder, Winter 1974 and Summer 1975
SEAS/YR:	June/76	SITE PREP:	Broadcast burn, Fall 1974?
STOCK:	Pl ?, Sx ?		

Performance

STATUS:	NSR		
AVG. HEIGHT:	Pl 270 cm (10 yrs) Sx 170 cm	VIGOR:	Pl excellent Sx good

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Epilobium angustifolium	8	56	100
Rubus parviflorus	9	28	100
Populus tremuloides	14	440	80
Sorbus sitchensis	5	60	40
Cornus sericea	9	80	40

History

This site was burned in 1974 but not planted until 1976. The planting record is unclear.

Site Impact

Judging by the intact nature of the 6-8 cm thick duff layer, the actual burn impact was fairly low.

Brush Problems

Aspen dominates most of the block and is now overtopping many planted pine and spruce. Distribution, however, is very uneven. Portions of this block will soon be NSR as an aspen canopy forms over the planted seedlings. Numerous aspen stems are present in the adjacent unlogged stand.

Assessment

Where freely growing, pine is still growing well, with average leader growth of 45 cm. Spruce, apparently naturally established, is also performing well, with leader growth averaging 30 cm.

Implications

A light fire may stimulate aspen suckering. A pre-harvest hack-and-squirt treatment may be appropriate on mixed stands, if carried out well before logging. Alternatively, falling of residual aspen at the time of logging followed by herbicide application will be necessary.

CASE STUDY 10.

Site Data

DISTRICT:	Fort St. John	SOIL TEXT:	Silt Loam (to SiCL)
LOCATION:	Commotion Ck.	ASPECT:	East
BEC UNIT:	SBS j3 (upper)	GRADIENT:	3-7%
ECOSYSTEM:	Mesic - Subhygric	ELEVATION:	980

Silvicultural data

SPECIES:	Pl	LOG. METHOD:	Wheel skidder, 1982
SEAS/YR:	Spring/84	SITE PREP:	Windrow and burn, 1983
STOCK:	Pl 2 + 0 BR		

Performance

STATUS:	SR		
AVG. HEIGHT:	Pl 24	VIGOR:	Pl poor

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Ribes lacustre	6	26	100
Rubus idaeus	7	22	100
Equisetum arvensis	8	21	100
Carex spp.	6	61	100
Calamagrostis canadensis	4	70	80
Sambucus racemosa	3	55	60

History

This site was conventionally logged in 1982, windrowed and burned the following year, and planted to bareroot pine in spring of 1984.

Site Impact

The windrowing treatment was drastic. Almost no duff layer is present - it was presumably transported to the windrow and burned. Soils are medium to moderately fine-textured and shallow over bedrock. An "Ah" horizon about 25 cm thick overlies a "C" horizon. Mineral soil exposure runs about 90% on this site. Although the site preparation treatment was drastic, the soil contains substantial incorporated organic matter (in the form of an Ah horizon), and therefore should not experience a significant loss of productivity.

Brush Problems

Brush competition is low on this site. The treatment was very effective at setting back competing vegetation.

Assessment

Seedling survival is fairly poor and shoot die-back appears to be common. Seedlings were planted alongside berms created by windrowing.

Implications

It is frequently difficult to state whether poor performance is due to stock type, site preparation, or adverse ecological conditions. However, the harsh conditions following severe windrowing may aggravate the poor growth because of poor stock or difficult planting conditions.

CASE STUDY 11.

Site Data

DISTRICT:	Fort. St. John	SOIL TEXT:	Silt Loam (to SiCL)
LOCATION:	Commotion Ck.	ASPECT:	Northwest
BEC UNIT:	SBSj3 (upper)	GRADIENT:	3-15%
ECOSYSTEM:	Mesic - Subhygric	ELEVATION:	920

Silvicultural Data

SPECIES:	Sx	LOG. METHOD:	Wheel skidder 1980
SEAS/YR:	Spring/83	SITE PREP:	Windrow and burn 1982
STOCK:	Sx 2 + 0 BR		

Performance

STATUS:	partially SR		
AVG. HEIGHT:	Sx 37	VIGOR:	Sx fair

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Carex spp.	13	68	100
Ribes lacustre	2	20	100
Rubus idaeus	3	26	100
Equisetum arvensi	12	21	100
Calamagrostis canadensis	2	68	80
Salix spp.	2	45	60

History

This site was conventionally logged in 1980, then partly windrowed and partly spot-piled 2 years later. Planting of bareroot spruce stock was carried out the next spring in 1983.

Site Impact

The treatments were moderately severe, producing substantial mineral soil exposure. Much of the duff layer has disappeared into the windrows or piles, but some has been buried. The moderately severe brush blade treatment has achieved a reasonable balance between scalping for mineral soil exposure and vegetation control on the one hand, and conservation of organic matter on the other.

Brush Problems

Brush competition is fairly low, and not yet threatening planted seedlings. Seeding-in of balsam poplar and willow may be a problem later on.

Assessment

Microsite selection for planting was fairly indiscriminate. Seedling performance is highly variable. Best growth appears to be where seedlings were placed near to the base of berms. Seedlings planted on tractor paths appear chlorotic, but are still free from vegetative competition. Frost-heaving is evident in a few seedlings where planted on mineral soil. Most seedlings exhibit mild chlorosis in older foliage, perhaps suggesting nitrogen deficiency. Natural regeneration of pine is sparse, despite well-distributed cones.

Implications

Poor initial performance is frequently due to poor stock quality (bareroot spruce) combined with poor microsite selection and the general environmental difficulties associated with high elevation. Plantations that experience a combination of disadvantages are usually doomed in the northern Interior.

CASE STUDY 12.

Site Data

DISTRICT:	Fort St. John	SOIL TEXT:	Silt Loam (to SICL)
LOCATION:	Osborne Fire	ASPECT:	Northwest
BEC UNIT:	BWBSc	GRADIENT:	0
ECOSYSTEM:	Subhygric	ELEVATION:	?

Silvicultural Data

SPECIES:	Sw	LOG. METHOD:	Natural fire 1984
SEAS/YR:	Spring/85	SITE PREP:	Winter windrow, burn following spring, Bråcke mounder for microsite preparation
STOCK:	Sw 1 + 0 PSB 313		

Performance

STATUS:	SR		
AVG. HEIGHT:	Sw 19	VIGOR:	Sx fair

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Calamagrostis sp.	60	50	100
Equisetum arvensis	4	22	100
Epilobium angustifolium	.5	15	100
Salix sp.	7	52	60

History

This rehabilitation site north of Fort St. John was burned by wildfire in 1984. It was subsequently winter windrowed, treated by a Bråcke mounder, and planted to Sw in 1985.

Site Impact

The site is situated on a large expanse of flat-lying glaciolacustrine silts and clays. The fire was not hot enough to kill grass rhizomes, and subsequent windrowing (in winter) caused minimal and local disturbance to the duff layer (except under the burned windrows, where mineral soil was exposed and charred).

Brush Problems

Within 2 years after the fire, reedgrass had attained a high cover, and posed a threat to surviving seedlings. The grass forms a continuous mat, presumably from rhizomes present in duff layer. Burned windrow areas are largely free from grass, but willow is more prominent there.

Assessment

Mounds are inconsistent in quality, ranging from very hard and dry clods of mineral soil to loose flaps of sod which threaten to flip back. Because many of the mounds appear to be unsatisfactory, planters placed seedlings in depressions. Although still too early to be sure, seedling growth appears poor. Frost-heaving has killed numerous seedlings. Many are chlorotic to various degrees, and have deformed leaders and stems.

Implications

Planting in the depressions created by mounder may cause poor growth of spruce seedlings if they are subjected to flooding, low soil temperatures, and unfavorable subsoils. Raised microsites are highly desirable on the lacustrine soils in the BWBS, not only because of improved drainage and soil temperature, but because of a height advantage conferred on the seedling in the face of intense grass competition.

CASE STUDY 13.

Site Data

DISTRICT:	Fort. St. John	SOIL TEXT:	Silt Loam
LOCATION:	Aikman Creek	ASPECT:	East
BEC UNIT:	BWBSd2	GRADIENT:	15-25
ECOSYSTEM:	Mesic - Subhygric	ELEVATION:	950?

Silvicultural Data

SPECIES:	Sw	LOG. METHOD:	?
SEAS/YR:	?/77	SITE PREP:	None
STOCK:	Sw 2 + 1 BR		

Performance

STATUS:	NSR		
AVG. HEIGHT:	Sw 18	VIGOR:	Sx poor

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Calamagrostis spp.(dead)	8	-	100
Rosa (dead)	12	-	100
Epilobium angustifolium (dead)	11	-	100
E. angustifolium (live)	1	17	80
Alnus viridus (live)	15	150	40
Equisetum sylvestris (live)	3	16	100

History

This site was originally planted in 1977 to large transplant stock, but with no other treatment. In 1985, Roundup® was aerially applied in preparation for replanting in the summer of 1986.

Site Impact

As of 1986, little site impact has been evident.

Brush Problems

The herbicide appears to have been very effective against reedgrass, although the remains of the grass form a coherent mat which needs to be cleared away before planting to allow soil warming. (Soils were very cold beneath the mat even in August). Sitka alder was little affected by the herbicide, but many bushes were grazed back to a constant 40 cm (snowdepth?).

Assessment

By 1986, only an estimated 300-400 stems per hectare of the original planted seedlings remained, and these were in poor condition. Surviving spruce seedlings exhibited very poor form, and virtually no root egress from the rootball (even after 9 years). Residual balsam was performing reasonably well, but was adversely affected by the herbicide.

Implications

The very poor growth of spruce seedlings in this case study suggests that in such conditions (i.e., BWBS mesic to subhygric sites) planting large stock is not sufficient without some form of site prep, with or without chemical treatments.

CASE STUDY 14.

Site Data

DISTRICT:	Fort St. John	SOIL TEXT:	Silty Loam (to SiCL)
LOCATION:	Aikman Creek	ASPECT:	West
BEC UNIT:	BWBSd2	GRADIENT:	10-15%
ECOSYSTEM:	Mesic	ELEVATION:	1066

Silvicultural Data

SPECIES:	Pl	LOG. METHOD:	Wheel skidder, 1966-1974
SEAS/YR:	?/77	SITE PREP:	Blade scarification
STOCK:	?		

Performance

STATUS:	SR (barely)		
AVG. HEIGHT:	Pl 101	VIGOR:	Pl poor

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Calamagrostis sp.	82	116	100
Epilobium angustifolium	7	73	100
Rubus idaeus	5	63	100
Equisetum sylvestris	6	37	60
Alnus viridus	30	220	20

History

This site (in the same valley but opposite Case Study 13) was successively logged between 1966 and 1974, but was not planted until 1977. Presumably because of its westerly aspect, it was planted to pine instead of spruce.

Site Impact

No evidence of the site impact was observed in 1986.

Brush Competition

The site is dominated by a dense sward of reedgrass, except for clumps of aspen, poplar and alder, which may eventually take over.

Assessment

Planted pine are mostly free-growing, but height growth is diminishing. Leader growth averages 21 cm. Root egress is very poor and several stems are unstable. Reedgrass quickly colonized the site, judging by the stem deformities in some pine saplings. In one case, a stem ran horizontally above the mineral soil (and beneath the grass mat) for about 50 cm before attaining an upright stance. Most saplings show some chlorosis.

Implications

Poor performance of pine can, in places, be attributed to severe grass competition and poor root egress due to low soil temperature. Where grass is present, effective site preparation combined with follow-up brushing and weeding are necessary to establish plantations on mesic, grass-prone sites.

CASE STUDY 15.

Site Data

DISTRICT:	Fort St. John	SOIL TEXT:	Silty Loam (to SiCL)
LOCATION:	Kobes Creek	ASPECT:	West
BEC UNIT:	BWBSc2	GRADIENT:	5%
ECOSYSTEM:	Mesic	ELEVATION:	850

Silvicultural Data

SPECIES:	Sx	LOG. METHOD:	Wheel skidder, 1972
SEAS/YR:	?/82	SITE PREP:	None
STOCK:	?	REHAB:	V-plow,1980

Performance

STATUS:	SR		
AVG. HEIGHT:	Sx 53	VIGOR:	Sx good

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Calamagrostis sp.	15	120	100
Epilobium angustifolium	2	75	100
Equisetum sylvestris	12	28	100
Betula papyrifera	17	310	80
Petasites palmatus	5	15	80
Alnus viridus	30	350	20

History

This site was conventionally logged in 1972, and left without treatment for natural regeneration. Although some spruce naturally established, the plantation became NSR by 1980. At that time it was treated by V-plow, then planted to spruce 2 years later in 1982.

Site Impact

The V-plow created trails running up and down the gentle slope. It scraped off a variable surface layer, in places exposing a slightly gleyed subsoil. Mixing of mineral and organic matter was achieved along the edges and seedlings planted here were robust.

Brush Problems

The site is dominated by birch, alder and willow. Trails are more or less free from competing vegetation, except for willow, which is beginning to establish. The inter-trail areas are heavily brushed-in.

Assessment

Natural spruce in the inter-trail areas was conserved and, in 1986, was as much as 180 cm tall, with 28-cm leader growth. Seedlings planted at the base of berms or on trail surfaces were growing poorly. Some stems were deformed by falling vegetation (presumably during winter). Many planted seedlings were not freely growing, and tending will be necessary before too long. Seedlings on the north side of the trail appeared to be outperforming those on the southern side, possibly because of greater insolation and earlier soil warming. Average leader growth was only 10 cm.

Implications

Intense brush competition frequently threatens plantations in this zone. V-plow treatment by itself does not sufficiently set back vegetation. An accompanying or follow-up chemical treatment is required. Mixing along trail edges may afford good planting spots, but careful planter selection is needed to take advantage of this. Tall brush remaining in the inter-trail spaces shades planted seedlings and limits potential growth.

CASE STUDY 16.

Site Data

DISTRICT:	Fort St. James	SOIL TEXT:	Very Fine Sandy Loam
LOCATION:	Teardrop Lake	ASPECT:	N/A
BEC UNIT:	SBSe2	GRADIENT:	0-3%
ECOSYSTEM:	01. Mesic	ELEVATION:	760

Silvicultural Data

SPECIES:	Pl natural	LOG. METHOD:	Wheel skidder, Winter 1981
SEAS/YR:	N/A	SITE PREP:	Chain drag
STOCK:	N/A	SITE REHAB:	Velpar "L" spot-grid

Performance

STATUS:	NSR		
AVG. HEIGHT:	Pl 26	VIGOR:	Pl fair

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Populus tremuloides	18	195	100
Epilobium angustifolium	4	85	100
Petasites palmatus	1	15	100
Oryzopsis asperifolia	2	17	100
Rubus idaeus	2	16	80

History

This site was winter logged in 1981, chain dragged in 1982, then left for naturals. Poor recruitment followed and, by 1986, the opening was effectively NSR. In 1986, Velpar L was applied as a ground injection treatment on a 2 x 2 m grid pattern. About 12 L/ha were applied at a cost of about $310.00/ha (1986).

Site Impact

Dragging exposed mineral soil and caused some mixing, but more importantly it stimulated aspen suckering.

Brush Problems

Residual aspen were not felled. The resulting aspen cover is fairly heavy but not continuous. Aspen suckers were beginning to show effects of herbicide, but residuals were not yet affected.

Assessment

The natural regeneration failed to "catch." It is difficult to say why it failed, although the local forester (D. Roy, Canfor, Takla Division) suggested that seed burial was excessive, implying that equipment was too heavy. Even if the naturals did catch, aspen cover would still threaten them.

Implications

Dragging around aspen residuals is a prescription for future aspen problems. Pre-harvest selective girdling or hack-and-squirt may be successful in controlling the aspen problem. Otherwise, chemical follow-up within about 2 years after logging will be required.

CASE STUDY 17.

Site Data

DISTRICT:	Fort St. James	SOIL TEXT:	Very Fine Sandy Loam
LOCATION:	Teardrop Lake	ASPECT:	East
BEC UNIT:	SBSe2	GRADIENT:	5%
ECOSYSTEM:	Submesic	ELEVATION:	765

Silvicultural Data

SPECIES:	Pl natural	LOG. METHOD:	Wheel skidder, 1980
SEAS/YR:	N/A	SITE PREP:	Landings burnt, 1981
STOCK:	N/A		

Performance

STATUS:	NSR		
AVG. HEIGHT:	Pl 87 cm	VIGOR:	Pl good

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Alnus viridus	16	110	100
Epilobium angustifolium	7	70	100
Rosa acicularis	2	45	100
Spiraea betulifolia	2	32	80
Rubus parviflorus	1	15	60

History

This site was logged in 1981, then landings were burned for hazard abatement and no further treatment applied.

Site Impact

Possibly soil disturbance created during (summer?) logging was deemed sufficient to promote natural regeneration of pine. This was not actually the case. Although pine regeneration is good where disturbance had taken place (e.g., edges of skidtrails), it was not sufficient over the entire block.

Brush Problems

Brush competition is low.

Assessment

Cones are plentiful and open, but apparently seeds did not germinate. Dragging on this site would probably have allowed adequate germination.

Implications

Soil disturbance created during logging is usually not suitable for natural regeneration except possibly on subxeric or xeric sites. Because brush competition is low, a light to medium drag followed by planting of Pl would be needed for rehabilitation of this site.

CASE STUDY 18.

Site Data

DISTRICT:	Morice	SOIL TEXT:	Gravelly Loamy Sand
LOCATION:	McKilligan Lake	ASPECT:	Northwest
BEC UNIT:	SBSd	GRADIENT:	0-10%
ECOSYSTEM:	(7) Submesic	ELEVATION:	854

Silvicultural Data

SPECIES:	Pl	LOG. METHOD:	Wheel skidder, 1974-78
SEAS/YR:	?/83	SITE PREP:	Bräcke mounder, 1982
STOCK:	Pl PSB 1 + 0		

Performance

STATUS:	SR		
AVG. HEIGHT:	Pl 87	VIGOR:	Pl good

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Epilobium angustifolium	3	70	100
Achillea millefolium	2	45	100
Rosa acicularis	3	40	100
Calamagrostis rubescens	6	52	100

History

This site was progressively logged between 1974 and 1978, then left without any treatment. In September 1982, the site was treated by a Bräcke mounder, then planted to Pl plugs the next year.

Site Impact

The soils are moderately coarse Luvisols developed on morainal parent material. The duff layer is variable, averaging 4 cm but ranging from 0 to 7 cm. The 12-cm thick A horizon is friable and the underlying B horizon (Bt) is very firm and probably restricts rooting. The mounder created small (< 10 cm) mounds and similarly small depressions.

Brush Competition

Brush competition and slash load were both light.

Assessment

Selection of planting spots must have been difficult because of the presence of naturally established pine and spruce. Most seedlings were planted in the depressions and after 3 years show an estimated 80% survival. Frost-heaving has caused mortality in some cases. Vigor and height growth are variable: leader growth averages only 11 cm. This is in contrast to (older) naturally established pine which shows up to 60 cm of leader growth. Natural spruce is slowly growing (with average 11-cm leaders).

Implications

On blocks that are partially stocked with well-growing conifers and with thin duff layers, the use of the Bräcke mounder has limitations. Numerous planting spots created by the mounder may be missed because of proximity to existing seedlings, and commonly a number of healthy trees may be destroyed in the process. Planting in the depressions may make seedlings susceptible to frost-heave. Fill-in planting with a screefing clause would be alternatives under these conditions.

CASE STUDY 19.

Site Data

DISTRICT:	Morice	SOIL TEXT:	Gravelly Loamy Sand
LOCATION:	Heading Creek	ASPECT:	East
BEC UNIT:	SBSd	GRADIENT:	0-10%
ECOSYSTEM:	01-07 Mesic-Submesic	ELEVATION:	1000

Silvicultural Data

SPECIES:	Sx	LOG. METHOD:	Wheel skidder, Winter 1982
SEAS/YR:	Spring/84	SITE PREP:	Leno scarifier, 1983
STOCK:	Sx BR 2 + 0 ?		

Performance

STATUS:	SR		
AVG. HEIGHT:	Sx 27 cm	VIGOR:	Sx poor

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Spiraea betulifolia	6	35	100
Epilobium angustifolium	4	55	100
Rosa acicularis	9	28	80
Calamagrostis rubescens	6	75	60

History

This site was logged in 1982, treated with the Leno scarifier in 1983, and planted in 1984.

Site Impact

Soils are coarse-textured Luvisols developed on morainal parent material, with a discontinuous duff layer averaging 2 cm thick. Stoniness affected the operation of the Leno, but screefs (about 2 x 0.5m) were adequate. Because of the thin nature of the duff, the tines produced a depression in the screefs, with a ragged mound at their forward end.

Brush Problems

Brush competition is generally low.

Assessment

Most seedlings were planted in the pit of the screef. Survival is estimated at between 50 and 80%, and vigor is generally poor. Leader growth averages 7 cm. It is too early to tell if this plantation will be a failure as the bareroot seedlings may only now be recovering from planting shock. Natural pine establishment is fair, although the site would not be SR if left to naturals.

Implications

Poor initial growth is a common problem associated with spruce bareroot stock. Planting in the depressions created by the Leno may be acceptable on sites exhibiting pronounced soil moisture deficit. Careful selection of microsites in loosened soil on the northern edge of the screef should theoretically maximize growth, although frost-heave may be a problem.

CASE STUDY 20.

Site Data

DISTRICT:	Morice	SOIL TEXT:	Gravelly Sandy Loam
LOCATION:	Heading Creek	ASPECT:	N/A
BEC UNIT:	SBSd	GRADIENT:	0-2 %
ECOSYSTEM:	01-08 Mesic-Subhygric	ELEVATION:	1000

Silvicultural Data

SPECIES:	Sx	LOG. METHOD:	Wheel skidder, Winter 1982
SEAS/YR:	Spring/84	SITE PREP:	Leno scarifier, 1983
STOCK:	Sx BR 2 + 0 ?		

Performance

STATUS:	NSR		
AVG. HEIGHT:	Sx 15 cm	VIGOR:	Sx very poor

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Calamagrostis canadensis	37	55	100
Rosa acicularis	1	22	100
Spirea douglasii	11	37	60
Aster conspicuous	1	31	60
Epilobium angustifolium	2	42	60

History

This site was logged in 1982, treated with the Leno scarifier in 1983, and planted in 1984.

Site Impact

This site is identical to the previous case study except that it is located in a gentle draw and therefore is mesic to subhygric. The soils are similar in texture, but are moist below 5 cm. A weakly developed Ah horizon is present in places. The duff layer is about 4 cm thick. The Leno scarifier again created deep (up to 10 cm) depressions here.

Brush Problems

Brush competition is so far not heavy, except in patches where reedgrass has established.

Assessment

Seedlings were mostly planted in the depressions. Seedling form and vigor are very poor, with survival estimated at 20-40%. Natural Pl is present, with sporadic distribution.

Implications

Planting in the depressions may lead to very poor growth and survival because of cold soils and local flooding. Careful seedling placement may reduce mortality if microsites are chosen on the north-facing edges or on the ragged mounds, but this is not the ideal solution. A powered disc trencher may provide the range of microsites necessary for planting under these conditions.

CASE STUDY 21.

Site Data

DISTRICT:	Lakes	SOIL TEXT:	Gravelly Loamy Sand
LOCATION:	Andrews Bay (Ootsa Lk.)	ASPECT:	Variable
BEC UNIT:	SBSd (towards e1)	GRADIENT:	0-10 %
ECOSYSTEM:	01-07 Mesic-Submesic	ELEVATION:	905

Silvicultural Data

SPECIES:	Pl naturals	LOG. METHOD:	Wheel skidder ? 1969-70
SEAS/YR:	N/A	SITE PREP:	None
STOCK:	N/A		

Performance

STATUS:	SR		
AVG. HEIGHT:	Pl 297 cm	VIGOR:	Pl good

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Epilobium angustifolium	6	75	100
Petasites palmatus	2	11	100
Calamagrostis rubescens	8	57	60
Rubus idaeus	2	15	40

History

This site was conventionally logged in 1969-70, but was left for naturals without dragging.

Site Impact

The duff layer averages about 5 cm and is more continuous than in the previous site. Soil disturbance created by logging appears to have been minimal.

Brush Problems

Brush competition is low, particularly with respect to willow. Possibly the relative paucity of exposed mineral soil prevented the seeding-in of this species.

Assessment

Lodgepole pine is growing very well here, with leader growth consistently between 50 and 85 cm. Uneven distribution of trees is a problem, with competition within clumps and wasted resources in the open areas. Theoretically, a better distribution of naturals would have been obtained using dragging equipment, but the next case study contradicts this.

Implications

Expecting successful natural regeneration without dragging may lead to disappointing results. However, the intact nature of the duff layer may inhibit heavy willow competition, a species that can be a problem in these mesic to submesic sites. (Willow invaded the site in Case Study 22, which was dragged, and therefore contained more exposed mineral soil.)

CASE STUDY 22.

Site Data

DISTRICT:	Lakes	SOIL TEXT:	Gravelly Loamy Sand
LOCATION:	Andrews Bay (Ootsa Lk.)	ASPECT:	Variable
BEC UNIT:	SBSd (towards e1)	GRADIENT:	0-10 %
ECOSYSTEM:	07 Submesic	ELEVATION:	885

Silvicultural Data

SPECIES:	Pl naturals	LOG. METHOD:	Wheel skidder, 1969-70
SEAS/YR:	N/A	SITE PREP:	Chain dragged, 1970
STOCK:	N/A		

Performance

STATUS:	SR		
AVG. HEIGHT:	Pl 320 cm	VIGOR:	Pl good

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Epilobium angustifolium	12	92	100
Elymus sp.	.5	54	80
Salix sp.	68	425	40

History

This site is near the previous case study. It was logged in 1969-70, then chain dragged for naturals in 1970. Brushing and weeding were carried out in 1977.

Site Impact

Soils are coarse-textured Luvisols developed in morainal material. The duff layer is discontinuous, with numerous patches of bare mineral soil, but in places it is up to 10 cm thick. Mixing of mineral and organic material, including rotting wood, has taken place.

Brush Problems

Brush competition is low. Scattered clumps of willow overtop some Pl saplings, but do not threaten the plantation.

Assessment

Pine saplings are growing well, with leader growths ranging from 40 to 90 cm. Distribution is very uneven, nevertheless the site is fully stocked. Naturally established spruce is also present and growing well (leader growth 20-30 cm), although it is smaller than the Pl.

Implications

Irregular distribution frequently prevents naturally regenerated stands from fully using site resources. Chain dragging is not always very effective in distributing seeds and promoting superior spacing. The distribution of Pl may be very uneven, with substantial areas (e.g., up to 0.2 ha) devoid of trees. Moister sites in draws consistently fail without alternative treatment.

CASE STUDY 23.

Site Data

DISTRICT:	Lakes	SOIL TEXT:	Gravelly Sandy Loam
LOCATION:	Andrews Bay (Ootsa Lk.)	ASPECT:	Variable
BEC UNIT:	SBSd (towards e1)	GRADIENT:	0-5 %
ECOSYSTEM:	07 Submesic	ELEVATION:	895

Silvicultural Data

SPECIES:	Pl	LOG. METHOD:	Wheel skidder, 1969-70
SEAS/YR:	?/71	SITE PREP:	Broadcast burn, 1970
STOCK:	BR 2 + 1		

Performance

STATUS:	SR		
AVG. HEIGHT:	Pl 448 cm	VIGOR:	Pl good

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Epilobium angustifolium	1	45	80
Calamagrostis rubescens	1	30	60
Shepherdia canadensis	5	70	40
Spiraea betulifolia	3	35	40

History

This site was logged in 1969-70, burned the following summer (1970), and planted to Pl transplant stock (BR) in 1971.

Site Impact

The burn was believed to have been hot but no records of impact rank are available. The fire had consumed all the original duff. By 1986 there was still virtually no build-up of humus. The soil is a moderately coarse Luvisol developed in morainal material.

Brush Problems

Brush competition is very light.

Assessment

Pine growth is excellent, with leader growth averaging over 1 m. However, most trees exhibit nutrient deficiency symptoms. Most show moderate to severe chlorosis of older foliage, suggesting a nitrogen problem. An estimated 15-20% of trees show leader problems in the form of die-back or deformity. Trees here exhibit basal sweep, attributed to poor root placement during planting. According to the local silviculturist (B.Walker, Eurocan), slash accumulations were such that dragging was not an option. He suggests that a light impact burn followed by fertilizer application may have been a better choice.

Implications

High impact burns on sensitive sites may lead later to nutrient deficiency. Although height growth so far may be excellent, the deficiency symptoms bode ill for the future. According to Pojar *et al.* (1984), prescribed fire is not recommended on this ecosystem. Extreme nutrient deficiency may eventually take its toll on root development and height growth may be expected to drop off.

CASE STUDY 24.

Site Data

DISTRICT:	Lakes	SOIL TEXT:	Gravelly Sandy Loam
LOCATION:	Andrews Bay (Ootsa Lk.)	ASPECT:	Northeast by East
BEC UNIT:	SBSd (towards e1)	GRADIENT:	2-5 %
ECOSYSTEM:	07-01 Submesic-Mesic	ELEVATION:	912

Silvicultural Data

SPECIES:	Sx	LOG. METHOD:	Wheel skidder, 1974
SEAS/YR:	?/75	SITE PREP:	Broadcast burn, 1974
STOCK:	BR 2 + 1		

Performance

STATUS:	SR (barely)		
AVG. HEIGHT:	Sx 169 cm	VIGOR:	Sx good

Competing Species

	AVG. COVER %	AVG. HEIGHT cm	FREQUENCY %
Aster conspicuous	.5	8	20

History

This site was logged in 1974, burned the same year, then planted to transplant BR stock Sx in 1975.

Site Impact

The soils are moderately coarse Luvisols, virtually identical to previous case studies in this area, except that no duff layer remains. It has been entirely consumed by the fire, with no subsequent build-up. According to B. Walker (Eurocan), the fire was "very hot".

Brush Competition

Brush competition is virtually nil.

Assessment

Spruce performance is good for an 11-year-old plantation. Leaders average a respectable 34 cm, well above average for interior spruce in the SBSe1 (Pollack *et al.* 1985). However, all Sx are moderately to severely chlorotic, especially in older foliage. Naturally established pine, even though younger, in some cases exceeded planted Sx.

Implications

Severe nutrient deficiency in planted Sx is almost certainly due to the hot fire. It is interesting that despite the striking symptoms, height growth has been and continues to be very good. This is perhaps because nutrient loss following fire is to some extent compensated for by the elimination of competition for nutrients and for moisture. However, without nutrient additions, it is suspected that superior height growth will not continue. Natural Pl exhibits much greener foliage, suggesting that this species is much more conservative in its nutrient demand than is spruce.

APPENDIX 2. List of contacts

NAME	REPRESENTING	POSITION
Bob Baker	Canfor (Takla)	Forester
Lorne Bedford	Silv. Br. Victoria	Site Prep. Coord.
Robert Bowden	Prince George West	R/O Silviculture
Michael Breisch	Northwood	Forester
Mike Bruhm	Prince George Region	Refor. & Site Prep. Coord.
Brent Bye	Prince George West	Silv. Crew Coord.
Tan Calhoun	Lakes	District Silviculturist
John Casteel	Lakeland	Forester
Grant Cissel	Canfor	Forester
Mike Conners	Prince George Region	Silv. Planning Coord.
Norm Crist	Northwood	Forester
Derrick Curtis	Westar	Forester
George Davis	Fort St. James	R/O Silviculture
Heather Dawson	Prince George West	District Silviculturist
Craig Delong	Prince George Region	Research Ecologist
John Dunford	Canfor (Takla)	Area Forester
Rick Fahlman	Prince George East	District Silviculturist
Dave Greenley	Mackenzie	District Silviculturist
Frank Gunderson	B.C.F.P.	Forester
Brad Hawkes	C.F.S.	Fire Research Off.
John Henigman	Prot. Br. Victoria	Control Agent Specialist
Les Herring	Prince George Region	Research Officer
Bob Johnson	Smithers	R/O Silviculture
Rein Kahlke	Canfor (Takla)	Area Forester
Steve Knowles	Finlay F.P.	Forester
Cliff Kowalski	Peace Wood F.P.	Forester
Hank Krawczyk	West Fraser	Forester
Steve Lindsay	Fort Nelson	R/O Silviculture
Ivan Lister	Morice	R/O Silviculture
Gary Lloyd	Smithers	Silviculture Officer
Jane Lloyd-Smith	Smithers	District Silviculturist
Ann Macadam	Smithers	Asst. Pedologist
Angus McLeod	Prince George Region	Reg. Pedologist
George McKee	Quesnel	R/OSilviculture
Bob McMinn	C.F.S.	Res. Ecologist
Dave Menzies	Canfor	Forester
Randy Murray	Canfor (Takla)	Area Forester
Fred Newhouse	Smithers	Stand Tending Coord.
Jane Perry	Williams Lake	Stand Tending Coord.

NAME	REPRESENTING	POSITION
Dave Presslee	Northwood	Forester
Richard Prokopanko	Westar	Area Forester
Diane Renaud	Fort St. John Dist.	Silviculturist
Bob Richards	Prince George East	R/O Silviculture
Juha Salokannel	Canfor (Takla)	Area Forester
Liz Saunders	Morice	R/A Silviculture
Paul Sears	Clear Lake	Forester
Brian Smith	Morice	Site Prep. Coord.
Ordell Steen	Williams Lake	Ecologist
Wayne Thorp	Dawson Creek	formerly R/O Silviculture
Al Todd	I.S.S.	Silvicultural Consultant
Dave van Dolah	Vanderhoof	R/A Silviculture
Keith Van Tine	Lakes	R/A Silviculture
Charles von Hahn	Vanderhoof	R/O Silviculture
Brian Walker	Eurocan	Forester
Brian Wesleyson	Fort St. John	R/O Silviculture
Bill Williams	Prince George Region	Silviculture Officer
Cal Wilson	Dawson Creek	R/O Silviculture
Frank Wolfinger	I.S.S.	Silvicultural Consultant
Brian Zak	B.C.F.P.	Forester

APPENDIX 3. Questionnaire

Question 1. Please identify the subzones in which you have had experience in site preparation or rehabilitation.

	SBS	BWBS
Prince George	c,d,e1,e2,f,i, j,k1,k2,k3, l,o.	c1,c2,d1,d2
Prince Rupert	a,d,e.	
Cariboo	a,b,c,l,k1,k2,k3, e,j.	

With which one of these are you most familiar?

Question 2. In this subzone, which site preparation treatments are currently being used? (Please list in order of decreasing importance and indicate for which species the treatment is intended.)

Question 3. In the same subzone, which site rehabilitation treatments are being used?

Question 4. In your opinion, which ecological factor or factors are responsible for regeneration failure in your chosen subzones? Please rank by importance:

1	2	3	4	5
Unimportant		Somewhat Important		Very Important

Rank

1. Growing season moisture deficit
2. Low soil temperature
3. Excessive moisture
4. Poor root penetrability
5. Low nutrient supply
6. Winter kill
7. Snow damage
8. Competition from: Aspen / Other Brush
9. Pathogens or insects
10. Unusual climatic event

Question 5. In the same subzone, which silvicultural factors are responsible for regeneration failure? Please rank in importance:

1. Site preparation
    - no treatment
    - inappropriate treatment
    - appropriate treatment, not properly carried out
    - excessive delay in treatment

2. Planting
    - inappropriate species
    - inappropriate stock type
    - poor timing
    - poor planting techniques
    - poor planting site selection

3. Stand tending
    - lack of brushing and weeding
    - other cause (specify)

Question 6. Could you elaborate on the site preparation factors which you ranked 4 or 5 in the last question? (In other words, which treatments have led to NSR status, or poor growth?)

Question 7. In your experience, which treatment or combination of treatments (in the same subzone) have been most successful? In which sites are the treatment(s) applicable? (e.g., HG-SHG sites in the SBSk)?

Question 8. Of the treatment options open to you, which are falling (or have fallen) out of favor because of operability problems? (e.g., V-plow does not efficiently disperse slash, and so requires frequent reversals; or Leno patch scarifier is too difficult to operate on uneven terrain).

Question 9. Which treatment(s) would you like to see more frequently used in your area? On which sites? Why are they not more popular at present?

Question 10. Is site degradation caused by soil compaction or rutting a problem in your area? Would low ground-pressure equipment such as FMC or wide-tired skidders be acceptable, given their greater cost?

APPENDIX 4. Perception of regeneration problems (summarizing questionnaire response and interviews)

1. Ecological Problems

Questionnaire respondents and interviewees most frequently regarded low soil temperature as a "very important" ecological factor causing regeneration problems. It was understood that slow warming of the mineral soil in the early summer restricted root egress of both white spruce and lodgepole pine, and therefore contributed to "growth check" and/or poor performance. It was frequently cited as a reason for poor root development and growth slowdown in pine. The problem of low soil temperature does not exist independently but as part of a "factor-complex" associated with brush competition. Increasing soil temperature and, at the same time, reducing brush competition, was usually stated by questionnaire respondents as the objective of site preparation practices.

Brush competition was also regarded as highly important in all areas, although the specific type of brush differed between the BWBS and the SBS. Grass competition was seen as critically important in the former zone, whereas "other brush" problems were identified in the SBS. Aspen was cited as "important" or "very important" by most respondents throughout both zones.

No other ecological problems were consistently regarded as important in causing plantation failure. "Unusual climatic event", "winter kill", and "pathological agent/insects" were most frequently cited as "unimportant."

BWBS

Competition from reedgrass (*Calamagrostis* spp.) and low soil temperature were both regarded as very important factors by respondent silviculturists. In the BWBS, this grass is a member of many undisturbed forest ecosystems. Opening up the canopy by logging can lead to an explosive increase in cover. Low soil temperature was regarded here, as elsewhere, as important, and related to brush competition. The mat associated with reedgrass, either living or dead, effectively insulates the soil from solar insolation and warming (Case Studies 13 and 14).

Competition from aspen was perceived as being moderately important. Aspen is very much a natural component of these northern forests which, because of their fire history, persist as a mosaic of hardwood and softwood stands (Annas 1983). It is a very extensive species, common throughout the zone, and probably more abundant here than in any biogeoclimatic unit of the SBS (C. DeLong, pers. comm.). It has been estimated that over 400 000 ha are pure or predominantly aspen in the Peace TSA (Boateng 1984). Despite the abundance of aspen in this zone, it is second to reedgrass as the chief perceived villain in plantation establishment. The perception of aspen as an ecological problem is likely to change as it becomes a harvestable species.

Respondents of the questionnaire rated "unusual climatic event" as the third most important ecological factor. In the BWBS, this generally refers to chinooks - warm adiabatic winds descending from the Rocky Mountains which, when they occur in mid-winter, may desiccate young seedlings that protrude above the snow. Seedlings undergoing stress because of other causes during early establishment may be more vulnerable to "winter kill." Under certain conditions, insufficient frost hardiness may doom seedlings during the winter.

Excessive moisture was deemed an important factor in the BWBS. Subhygric or hygric sites receiving seepage during wet spring weather, especially following snowmelt, present particularly difficult problems in plantation establishment (H. Krawczyck, pers. comm.). They suffer from the combined effects of high watertables or poor aeration, low soil temperatures, and excessive brush competition. However, such sites pose regeneration difficulties throughout the study area.

Snow damage was not regarded as a problem. Indeed, the general feeling was that more damage was incurred because of too little snow, rather than too much.

Snowshoe hare damage was noted in pine plantations in some western portions of the BWBS near the foothills of the Rocky Mountains.

Root penetrability is perceived to be a problem, particularly in the fine-textured glaciolacustrine soils prevalent in the Peace River area. This can become a major regeneration problem when topsoils are removed and seedlings are planted directly in the subsoil (see Case Study 12, Osborne Fire).

SBSj1, j2, f, and n; "wet units"

Ecological conditions differ from those in the BWBS. Competition from brush, other than aspen, was perceived by questionnaire respondents to be the most serious ecological problem. Instead of reedgrass, the major competitors in young plantations were considered to be lady fern (*Athyrium felix-femina*), thimbleberry (*Rubus parviflorus*), red raspberry (*R. idaeus*), black twinberry (*Lonicera involucrata*), hellebore (*Veratrum viride*), devil's club (*Oplopanax horridus*), and fireweed (*Epilobium agustifolium*). Mesic and subhygric ecosystems are particularly brush-prone (Case Studies 6 and 7 in the SBSj2). Plantation failure was regarded as being disproportionately high in these ecosystems. For example, of Northwood's plantations in the SBSf, 84% of the total NSR is concentrated in the 29% of plantation area located in mesic (01.2) to subhygric (06) sites (D. Presslee, pers. comm).

Brush is less consistently a problem in drier ecosystems (Case studies 4, 5 and 8). Birch willow and cottonwood seed-in to exposed mineral soil after several years if a seed source is present, and can threaten slow-growing spruce seedlings (see Case Study 4). Although not seen as a problem in the SBSf, aspen can pose a definite threat to inappropriately prepared plantations in the j1 and j2 subzones (Case Study 9) through suckering.

Snow damage was considered by questionnaire respondents to be a "somewhat important" ecological factor, more so than in any other part of the study area. Snowfall is greater here than elsewhere. For example, Pine Pass (SBSj2) receives, on average, about 8 m between November and February. Snow damage is thought to be a problem for lodgepole pine, which does not shed snow as efficiently as spruce, and therefore may sustain mechanical injury. This effect may be particularly serious in recently spaced stands.

Remainder of SBS

Questionnaire respondents considered brush competition (both aspen and other species) and low soil temperature to be the most serious ecological factor in plantation establishment. Aspen is a problem throughout this area, with the exception of the SBSi subzone.

Respondents disagreed as to the importance of other factors, such as moisture deficit, excessive moisture, and root penetrability. Since most of these factors are site-specific, they are not easily summarized in a regional context.

2. Silvicultural Factors

Numerous silvicultural factors were cited as being responsible for plantation failure in the past. Lack of site preparation was the factor most frequently cited by questionnaire respondents across the study area. The failure to prepare sites adequately for planting was seen to be a major cause of backlog status and "no treatment" was considered to be a prescription, especially for plantation failure. Many blocks logged in the 1960's and 1970's were left, in anticipation of natural regeneration, without any treatment. Most of those sites are now backlog NSR. In the past, many sites were not treated and left for naturals, not because it was considered the best course of action, but because planting stock was not available. Other sites were planted without any site preparation, presumably because it was simply not prescribed (Case Study 1).

In some cases, sites that are adequately treated may contain small portions of land which, for reasons of terrain, heavy slash or access, may go untreated. These portions often develop into NSR and, although small in themselves, can add up to a significant area.

Lack of site preparation is most critical on brush-prone sites, which also tend to be "cold" sites because of soil moisture, vegetation cover, and duff layers. In drier ecosystems, planting can, in some circumstances, be successful without site preparation, but only if it is carried out immediately following logging and duff layers are not thick. Lack of preparation is mainly an historical factor, since most current sites today receive some form of treatment.

Excessive delay was also cited as being important. "Delay" was interpreted both as the time between logging and site preparation and the time between site preparation and planting. Respondents observed that delayed site preparation allowed the establishment of competing vegetation and reduced the effectiveness of mechanical treatments.

Prescribed fire, if delayed beyond the optimum time, can have a lower impact, and therefore may be less effective. Several questionnaire respondents stressed the need for planting as soon as possible following logging and site preparation. According to respondents, planting through existing vegetation has frequently doomed seedlings to an untimely death. Case Study 1 represents a block in which planting was delayed 4-5 years after logging.

Poor planting site selection by planters was also rated as an important factor. This mostly refers to planting in the compacted trails of V-plows (Case Study 6), or in the flood-prone depressions left by patch scarifiers or mounders (Case Study 12). The generally poor performance and high mortality of these seedlings is now changing the attitude to microsite selection, and most of those interviewed confirmed the need for better training and supervision of planters in this regard. However, on some blocks, poor placement of seedlings was more a function of poor (or non-existent) planting spots (Case Study 12).

Lack of, or insufficient, brushing and weeding was regarded as an important cause of plantation failure in every region.

In addition to site preparation and stand tending problems, a major complaint was the quality of planting stock. Both quantity and quality of seedlings were regarded as important contributing factors in the accumulation of backlog NSR. Some silviculturists felt that seedling physiology is a more important factor than site preparation in determining plantation success or failure.

Spruce bareroot stock (2+0) was most frequently cited as an example of a poor type. Since this stock type is being phased out, and since constant improvements in quality and quantity are taking place, these complaints are more relevant to past plantation failure than to current failures. Stock quality is also affected by a variety of conditions operating between the time of lifting and planting. However, handling was not perceived to be a consistent problem by the respondents.

Poor planting techniques and incorrect timing were ranked as important. In the BWBS, planting windows are narrow: soils are cold and wet during the early part of the growing season. As well, access is problematic on the predominantly fine-textured soils. In contrast, summers in this continental climate can be warm and dry, and this is usually aggravated by persistent winds. Therefore, timing of the planting operation can be critical.

Species selection was generally perceived as unimportant. Lodgepole pine and white spruce are the only species planted in any quantity, although some silviculturists have expressed an interest in trying out black spruce (*Picea mariana*) and tamarack (*Larix laricina*) for certain sites. Pine is generally established from natural regeneration in submesic to subxeric sites. On these drier sites, it appears to outperform spruce significantly. On mesic sites, initial height growth of pine is still superior, but later growth trends are in doubt (Case Studies 1, 8 and 9). Growth reductions after initially promising height increments were observed in a number of plantations, especially where reedgrass competition has developed (Case Study 14).